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Some New or Noteworthy Industrial Raw Materials of Plant Origin[1]

In this selective review of surveys made by the Georgia Institute of Technology, attention is drawn to some new or as yet little-exploited sources of fats, oils, waxes, gums, resins and oleoresins that may some day become important supplements to the longer established sources of these industrially valuable plant extractives.

W. H. HODGE[2]

Fats and Oils

The world's 1951 production of the principal fats, oils, and oilseeds—all in terms of fats and oils—has been estimated at a record 25,850,000 tons, according to the Foreign Agricultural Service. For the first time since World War II the output of fats and oils was sufficient to restore the per capita supply to approximately the prewar level.

According to latest figures, the United States is now the largest single source of surplus fats and oils, exports of soybean and cottonseed oils being especially important. This country contributes to the production of six widely used oilseed crops, and very heavily to three of them—cottonseed, soybean, flaxseed. In recent years three others—peanut, tung, olive—have become increasingly important. In 1952, for the first time, the United States produced a significant quantity of a seventh oil crop—castor beans.

In recent years domestic production of castor beans has been increasing so that now about one-seventh of the United States requirements is furnished by farms in California, Arizona, Texas, Oklahoma, and neighboring States. Development of domestic supplies has been greatly dependent upon the successful breeding of varieties suitable to North American economic and edaphic conditions. Considerable progress in this direction has been made by the United States Department of Agriculture, which has a program to encourage the production of castor beans in this country. For 1952 castor beans were produced under the program on about 200,000 acres in areas within the states of Arizona, Arkansas, California, Oklahoma, and Texas.

Early in 1952, at the request of the Munitions Board, a program intended to develop a domestic supply of 34 million pounds of castor oil was undertaken. This program involved plantings of 76,000 acres of castor, 75 percent of which was allocated to Texas and Oklahoma. These plantings should yield about 40,000 tons of castor seed and about 34 million pounds of oil, or about one-third

[1] Under the general title "Industrial Raw Materials of Plant Origin", five bulletins have been issued by the Engineering Experiment Station, Georgia Institute of Technology. The work reported upon in these publications was sponsored by the Section of Plant Introduction, Agricultural Research Service, United States Department of Agriculture, through funds of the Research and Marketing Act of 1946. The present digest is a somewhat revised selective summary of Bulletins 13 (I. Recent Developments in Fixed Vegetable Fats and Oils) and 15 (II. Recent Developments in Vegetable Waxes, Gums, and Resins), authored by T. A. Wastler, P. M. Daugherty, and H. H. Sineath, and issued in 1952 and 1953.

[2] Section of Plant Introduction, Plant Industry Station, Beltsville, Maryland.

of the normal domestic consumption of this oil.

The long-term trend in domestic consumption of castor oil has been upward and is likely to continue so in the future. Whether or not domestic castor beans can compete on the open market with imported beans is still to be determined; it is also unknown whether castor beans can compete effectively with other crops.

A new use for castor oil has been reported. It is as the plasticizer in a new lightweight material consisting of a nitro-cellulose-based compound on cotton sheeting. Certain advantages exist over ordinary oilcloth in that the new material is washable, stain and ink resistant, and waterproof (3).

Black Spruce Oil (*Picea mariana* (Mill.) BSP.). An estimated five million pounds of black spruce oil are available annually from Ontario, calculated from the amount of foliage cut. The perfume industry can use only a small amount of this, and new uses must be found. Black spruce oil is one of the richest natural sources of bornyl acetate and may also be used for synthetic camphor (34).

Gokhru Oil (*Tribulus terrestris* L. ?). Gokhru, from India, has been mentioned as a promising source of an oil said to have excellent drying properties. The yield is estimated at 500 to 600 pounds (30 to 33 percent semidrying oils) per acre. The cake is high in phosphorus and nitrogen (4).

Grapeseed Oil (*Vitis vinifera* L.). The oil pressed from the seed of wine grapes has been used in the paint industry in Italy for 20 years and could probably be made available in this country. It could play an important role in the protective coatings industry when other fatty oils are scarce. The oil has a slightly higher viscosity than linseed oil and, when pigmented with zinc oxide, yields paints of better moisture impedance than corresponding linseed oil paints (6).

Kamela Oil (*Mallotus philippensis* (Lam.) Muell. Arg.). Indian scientists are investigating kamela oil which is said to be a substitute for tung oil. The oil, extracted from the seeds of the kamela tree, dries to a natural wrinkle finish without application of heat. It is generally better than tung oil, and the seed has an oil content of about 40 percent. The glandular hairs of the fruit yield a well-known orange-red permanent dye. Previous development as an oil crop has been hampered by the oil extraction process involving expensive organic solvents (7, 16).

Mowrah Oil (*Madhuca* spp.). The seeds of the Indian species *Madhuca longifolia* (L.) Coville and *M. indica* Gmel. are the sources of this oil. Mowrah oil has drawbacks for edible purposes—high acidity, deep color, unpleasant odor, high unsaponifiable content. Alcoholic refining, however, results in an improved product, and hydrogenation of the refined oil gives products similar to mutton tallow and cocoa butter (4).

Nim (Neem) Oil (*Azadirachta indica* (L.) Juss.). This oil, obtained from the seeds of a tree of India and Ceylon, compares favorably with other vegetable oils and, when hydrogenated, can be used for making high-grade soaps or high-melting stearins (4). It also contains a readily extractable bitter principle of pharmaceutical interest (8).

Pisa Fat, Khakan (Kokum) and Phulwar Oils. Studies of Indian pisa fat, taken from the seeds of the pisa tree (*Actinodaphne hookeri* Meissn.), as a possible substitute for coconut oil indicate that the mixed fatty acid of the kernel fat is 96 percent lauric acid and four percent oleic acid. The seed has a kernel rich in fat and an outer covering which is removed before crushing. Average samples of the seed yield 48 percent fat by solvent extraction, or 32 percent fat by hot expression. The seed contains 31 percent foreign matter and

shells, six percent moisture (24). Recent research in India has also indicated that khakan and phulwar oils can replace coconut oil in soapmaking (9). Khakan oil is obtained from the small black seeds of *Garcinia indica* (Thou.) Chois., whereas phulwar oil or butter is derived from the seeds of *Madhuca butyracea* (Roxb.) Macbride.

Queenroot Oil. *Stillingia sylvatica* L., commonly known as "queen's-delight" or "queenroot", is a native of the southern United States from Virginia south to Florida and west to Texas. A root extract of it has had medicinal use for many years, and recent investigation has shown that the seed oil may be suitable as a drying oil for paints and varnishes (19).

Rice Bran Oil (*Oryza sativa* L.). A recent development in the industry is the recovery of oil from rice bran. Texas, Arkansas, and Louisiana produce three-fourths of the rice grown in the United States. About ten percent of rough rice is milled out as bran, containing 15–17 percent oil. In the fall of 1949 a continuous solvent extraction plant, having a capacity of 80 tons of rice bran per day, began operating in Houston. Two other plants have been placed in operation since then. These three plants have a combined capacity equivalent to more than half of the total rice bran produced in the Southwest. Other plants are being planned for Arkansas and Louisiana (28).

Safflower Oil (*Carthamus tinctorius* L.). This Old World oil is well established in the commercial market, but interest in its production in the United States is of fairly recent date. The major foreign producing areas are Egypt, India, and the Orient. Basically, safflower is a drying oil crop, but the meal remaining after the oil has been extracted is used as a livestock feed because of its high protein content. Safflower oil has aroused considerable interest both from the farmers in the western United States, who have found it profitable to grow the seed as a cash crop, and from alkyd resin producers and manufacturers, who have found good qualities in the oil. The development of new safflower varieties has increased yields per acre from 250 to 2500 pounds for dry land, and from 1,000 to 4,000 pounds for irrigated land. Most domestic safflower is grown in California's Sacramento Valley where in 1953 the 45,000 acres planted yielded 28,000 tons of seed.

Stand oil prepared from safflower seed oil was similar when compared to the corresponding linseed oil product. Isomerization was tried in the presence of anthraquinone, nickel-carbon catalyst, and activated silica; a modified oil having good drying properties was obtained with the first two catalysts mentioned. Varnishes of medium oil range with the ester gum made from the treated oil were similar to the corresponding linseed oil varnishes. Its white paint containing titanium dioxide gave films similar to those of linseed oil paints, but the color retention was better (33).

The polymerization rate of safflower oil is sufficiently rapid to warrant its use on a commercial scale; with proper choice of polymerization temperature, safflower can be bodied at the same rate as linseed. The increasing rate at which safflower bodies in the high viscosity ranges invites further investigation. Safflower oil bleaches considerably better than linseed oil and is equal to or better than soya in this respect (31).

Sesame Oil (*Sesamum indicum* L.). Sesame oil is the principal oil of India and has been produced there as well as in China since ancient times. For the past eight years an intensive research program has been under way to develop new strains and varieties of sesame suitable to the mechanized agriculture of the United States. This oilseed yields more oil to the acre than any other annual oilseed. In the past it has not been

amenable to mechanical harvesting because of its tendencies to ripen unevenly and to drop its seed at maturity. This oil has many possible uses and is now being utilized for making shortenings, cooking oils, and margarine, and in soaps, drugs, paints, and insecticides. The pressed cake or meal makes an excellent livestock feed because of its high protein content. The oil and seed keep for several years without becoming rancid. New, non-shattering varieties of the plant have recently been developed, and trial field plantings have been made during the past year. The present oil mills of the South could, with only minor modifications, be equipped to extract oil from sesame seed (18*a*, 28).

Sorghum Grain Oil (*Sorghum vulgare* Pers.). Sorghum grain has been found to contain two-thirds as much oil as corn and 50 times more wax. The wax is similar to carnaúba and could be extracted from the unground grain by hot solvent. The grain oil was found to be similar to corn oil and could be used as a substitute for salad oils or hydrogenated and made into oleomargarine (26).

Sunflower-seed Oil (*Helianthus annuus* L.). This oil has been in fairly wide production in other parts of the world for some time. It is sometimes used as an extender for some of the major drying oils, but it is usually considered an edible oil. Recently it has attracted attention in the United States, and some research has been conducted to determine its properties. After three years exposure to laboratory temperatures there was no development of rancidity, chemical changes, or off-flavor. The oil, when stored under refrigeration, showed no precipitation or separation. The meal contained 52.5 percent protein (23).

Waxes

Vegetable waxes, while representing only about three percent of the total volume of waxes consumed in the United States, account for about 25 percent of the total value of waxes consumed. In spite of the relatively small percentage of vegetable waxes used, the actual volume used is considerable, amounting to about 31.5 million pounds in 1950 and 26.3 million pounds in 1951. The costs of vegetable waxes are so high compared to those of other waxes that only certain properties which have not yet been duplicated in lower-priced waxes keep the demand for them active.

A few fields consume considerable quantities of wax, but, in general, wax products go into a broad variety of applications in a great many industries. Purchases are frequently made in fairly small quantities. Vegetable waxes are consumed in large quantities in polishes and carbon paper, with a fair-sized amount of candelilla wax being used in chewing gum. The polish industry uses more types of wax than any other. Of the 34 million pounds utilized annually in this industry, about one-half is paraffin and one-quarter is carnaúba. In carbon paper manufacture rough estimates indicate that, of about 6.5 million pounds of waxes consumed annually, four million pounds are carnaúba, one million pounds are ouricuri, and the balance is divided among candelilla, sugar cane, and montan waxes. New methods of determining the presence of additives or adulterants in waxes have been developed, and many carnaúba substitutes have been investigated. Perhaps the most significant recent development in the vegetable wax industry was the 1952 decree by the Mexican government prohibiting exploitation of candelilla wax. In 1954 this decree was still in effect.

Carnauba Wax (*Copernicia cerifera* (Arr. Cam.) Mart.). The fan-shaped leaves of the carnaúba palm of northeastern Brazil have been the primary source of vegetable wax for nearly a century and a half. In recent years the industry has been influenced by the

growing trend toward the use of machines to extract the powdery wax from the leaves. This method increases wax output, as considerable amounts are wasted when the hand method is used.

During recent years the advancing prices of carnaúba, the most widely used vegetable wax, have compelled its users to look for less expensive replacements and to investigate possible new wax sources. Five classes of waxes are available for consideration: animal waxes, synthetic waxes, petroleum waxes, vegetable waxes, and composition waxes. Representatives of all of these classifications have been tried, but carnaúba is still preferred by most users.

A satisfactory substitute for carnaúba wax must have several important characteristics. Not only must it possess high gloss and hardness and have a high melting point (Federal specifications call for a softening point for the solids of not less than 80° C.), but it must also have good emulsifying characteristics. The emulsified wax must not be a cloudy liquid but a transparent one, especially when laid down in thin layers. In addition it would have to exhibit characteristics of toughness, water repellency, absence of tack, and light color. While the development of synthetic waxes has progressed in recent years, it has made only small inroads on the demand for carnaúba.

Several vegetable waxes have been widely used as substitutes for carnaúba wax, although none has proved entirely satisfactory. Many others have been mentioned as possible substitutes, but most of these have never been commercially developed to any great extent. The market is open for good, moderately priced vegetable waxes.

Candelilla Wax (*Euphorbia antisyphilitica* Zucc.). This wax occurs as a whitish coating on the succulent leafless stems of a plant native to the desert areas of northeastern Mexico, where most of the material of commerce originates, and to the Big Bend region of adjacent Texas. It has been used successfully as an extender for carnaúba stocks. The wax itself is not entirely suitable as a replacement for carnaúba, since the melting point is somewhat low and the commercial wax usually contains a considerable quantity of resinous components which impart an objectionable tackiness. Recently the high prices asked for candelilla wax have hindered its use to supplement carnaúba wax. In addition, candelilla is employed for various uses in which carnaúba is not suitable.

Because of excessive exploitation and a resulting decrease in production in recent years, candelilla harvesting has been prohibited in Mexico since 1952 by Presidential decree.

A bulletin reporting on an industrial survey on candelilla was issued in 1953 by the Georgia Institute of Technology.

Ouricuri or Licuri Wax (*Syagrus coronata* (Mart.) Becc.). This wax is somewhat similar to carnaúba in color and hardness but is cheaper in price. It has been used as a carnaúba substitute in floor waxes, shoe creams, and other polishes, although its higher resin content makes it somewhat inferior. It has been in the trade nearly 20 years.

Ouricuri wax is derived from the undersurface of the leaves of *Syagrus coronata*, a palm inhabiting dry "caatinga" areas in the Brazilian states of Pernambuco, Bahia, and Minas Geraes. The wax is removed by crude methods—scraping from the leaf with a knife, melting, and straining (32).

Sugar Cane Wax (*Saccharum officinarum* L.). Sugar cane wax is now being produced commercially from the clarifier muds resulting from sugar refining. Two methods of extraction have been proposed. One uses selective solvent extraction, the other employs vacuum distillation and a chromic acid

bleach. The crude wax as removed by solvent extraction is dark and soft, but it can be hardened and lightened by further refining and bleaching.

As a byproduct of cane sugar, the wax is available at present from sources in Australia, Cuba, California, and Louisiana, the imported wax being cheaper than that produced domestically. The yearly potential production of hard wax from the Cuban sugar mills alone would be about 60 million pounds, more than the world's combined production of carnaúba, ouricuri, and candelilla. Potential uses for the wax are in water-emulsion polishes, carbon paper, and paste polishes, as pigment dispersers, and for coatings (25, 32).

Cauassu Wax (*Calathea lutea* G. F. W. Mey.). The large leaves of cauassu, a tall perennial herb common in lowland areas of the West Indies, Central and South America, are potentially an important source of a commercial wax. Reports from Brazil indicate that the plant is easily grown in the wet tropics and that the wax yield is very good. About 30,000 seedlings can be planted on one acre of land and can be harvested a year after planting. In subsequent years two harvests may be collected annually; this would mean an annual crude wax yield of about 800 pounds per acre. The wax is removed from the dried leaves by mechanical beating or by extraction with hot water.

Preliminary tests indicate that the wax is similar to carnaúba, being nearly as hard, and can be used for many of the same purposes. It has the disadvantage of containing a resin which would require removal by solvent refining for some applications (35).

Douglas-Fir Bark Wax (*Pseudotsuga taxifolia* (Poir.) Britt.). The bark waste from Douglas-fir logging operations in the Pacific Northwest contains several extractives of commercial interest. Among these is a wax having a melting point in the range of 59° to 63° C. This wax is reported to be harder than beeswax, but not so hard as carnaúba; however, by chemical treatment the Douglas-fir wax can be made superior to carnaúba in this and other respects.

Since the bark also contains other marketable products, such as tannin and dihydroquercetin, the possibilities for economic production of the wax are increased. The bark contains 28 to 43 percent total extractives (32, 35).

Jojoba Wax (*Simmondsia chinensis* (Link) Schneid.). The seeds of this evergreen shrub, which is native to areas of the southwestern United States and adjoining Mexico, contain about 50 percent liquid wax. This liquid wax has properties which have suggested its use as a direct replacement for sperm whale oil. Possibly more important is the fact that the liquid wax can be transformed into a hard white wax by hydrogenation. Claims are that this hydrogenated wax could serve well as a replacement for carnaúba or other hard waxes of commerce. Experimental furniture and automobile polish compositions of jojoba wax proved to be equal to or superior to some of the popular polishes now on the market. Insufficient experimentation has been conducted to establish fully the potentialities of this wax from jojoba seeds. Since the wax is extremely pure, it might be advantageous to utilize other waxes as extenders in its compositions.

A bulletin reporting the results of a recent industrial survey on the potentialities of products of the jojoba plant was published by the Georgia Institute of Technology in 1953.

Sorghum Grain Wax (*Sorghum vulgare* Pers.). Sorghum grain contains about 0.3 percent wax with a reported melting point of 80° to 84° C. The wax is concentrated in the hull or bran and is removed by solvent extraction, and the

wax so removed is white. Comparison of the chemical characteristics of carnaúba and sorghum grain waxes indicates that sorghum grain wax has higher acetyl, acid, and iodine numbers and a lower saponification number than carnaúba wax. Sorghum grain wax also contains a lower percentage of esters and non-saponifiable material than carnaúba wax, and a hydrocarbon fraction which is absent from the latter (21, 26).

Gums and Resins

Agar and Other Seaweed Derivatives. Three types of Philippine seaweed (*Hypnea musciformis, Gracilaria lichenoides, G. canaliculata*) have shown promise as new sources of agar. Although the agar thus far prepared does not meet the specifications of the United States Pharmacopeia, it is believed that the quality could be improved by better methods of processing (18).

Laminarin, a derivative of seaweed, can be used as a component of talcum powder, as a substitute for blood plasma, and as a surgical powder readily absorbed by tissue (10).

Resin from Cashew Nut Shells (*Anacardium occidentale* L.). The cashew nut shell yields a liquid resin which, when combined with ethyl cellulose, forms a binder for pigments. This binder is especially useful for fabrics (2).

Mucilaginous Materials from Flaxseed (*Linum usitatissimum* L.). A mucilage suitable for use in medicinal preparations, in water paints, and for the manufacture of soluble fibers can be obtained from solvent- extracted flaxseed meal. The meal is air-separated and screened to obtain kernel and hull fractions, the kernel being high in protein and the hull high in mucilaginous materials. The mucilage can be removed by treating the hull fraction with acid and centrifuging, and it can then be concentrated by evaporation under reduced pressure and spray drying. The dried product is substantially protein-free and fiber-free, and forms an acceptable gel in a 4.4 percent aqueous solution (20).

Arabogalactan, Gum Arabic Substitute from Western Larch (*Larix occidentalis* Nutt.). Waste from the milling of western larch trees can be used to produce arabogalactan, a complex polysaccharide which resembles gum arabic in many respects. Arabogalactan is an odorless, colorless, water-soluble gum which is also a good source of galactose.

Production of the new gum requires a steeping process followed by concentration under reduced pressure and precipitation from ethyl alcohol. The material is purified by washing it with alcohol and low-boiling petroleum ether and is dried under vacuum. Between 7 and 17 percent crude arabogalactan—based on the oven-dry weight of wood—is obtained by this process.

The waste remaining after gum extraction can be used for fuel, pulp, or for other purposes. The Western Pine Association is now supplying research quantities of arabogalactan for trade evaluation (5, 11).

Guayule Rubber Production (*Parthenium argentatum* A. Gray). Guayule rubber has now been produced which is in every respect the equal of Malayan plantation rubber. It has been found that the freshly harvested shrub can be successfully processed for recovering its rubber without the use of chemical coagulants. The latex is coagulated by parboiling and mechanical treatment, although more experimentation is necessary before the most efficient method is established. Mill yields of rubber from the freshly harvested latex are generally high, but the method of preparing the shrub influences the recovery of the rubber hydrocarbon. When the shrub is conditioned and stored under conventional conditions of large-scale operation, the yield of rubber hydrocarbon

decreases with increasing storage time (36, 38).

West African Plant Gums. Two trees of tropical West Africa have been investigated recently as possible sources of gum. *Anogeissus schimperi* Hochst. exudes a water-soluble gum similar to mesquite gum. The aqueous solution of the gum is levorotatory and does not reduce Fehling's solution. Hydrolysis and cleavage liberate arabinose, galactose, and glucuronic acid. *Khaya grandifoliola* C. DC., one of the African mahoganies, yields a gum which, upon hydrolysis, gives galactose and a degraded polysaccharide composed of galactose, rhamnose, and galacturonic acid. This gum resembles that of slippery elm (27).

Maleo-pimaric Acid from Pine Gum. A fairly simple process for producing maleo-pimaric acid from pine gum has been described. Pilot-plant work indicates that the gum naval stores industry would have little difficulty in making the acid for commercial use. In printing inks the acid produces more brilliant and more workable azo pigments than the maleic-modified rosin now used. Good results have been obtained in using maleo-pimaric esters to plasticize polyvinyl chloride. The plasticizer, although not equal to the high-priced sebacates in performance, is able to compete with them on a cost basis. The acid soap has been used satisfactorily as an emulsifier in synthetic rubber production (37).

Terpene Hydroperoxides from Turpentine. It has been found that gum turpentine yields certain terpene hydroperoxides which are particularly suitable for use as catalysts in producing cold rubber (synthetic rubber made at relatively low temperatures to produce an unusually high quality product). The most promising of these are pinane hydroperoxide and menthane hydroperoxide.

Production of terpene hydroperoxides from gum turpentine needs no unusual equipment and is not complicated. Only two steps are required to make pinane hydroperoxide in concentrations of 50 percent, which is the catalyst strength now commonly used in the production of cold rubber.

Commercial production of these new chemicals, using gum turpentine as the raw material, would open a large new market to the gum naval stores industry which needs expanded outlets. At the same time the use of gum turpentine for this purpose would help to conserve the short supply of benzene, the raw material for today's most widely used catalyst for cold rubber (12, 14).

Turpentine-Based Lubricant. A high-quality synthetic lubricant, which may be used in place of castor oil derivatives, has been made from turpentine. The lubricant is composed of the synthetic esters produced from certain dibasic acids; pinic acid, apparently the most important of these, may supplant other acids because of its greater availability. The diesters formed from the dibasic acids are suitable for lubricating fluids or can be combined with a gelling material to form greases (1, 17).

New Uses for Tall Oil. Tall Oil (liquid rosin) is beginning to be widely used in the organic coatings industry. The fatty acid calcium soaps and the esters made from tall oil can be employed to advantage in lacquer and paint formulations. The largest single use of tall oil in the coatings industry is in the production of tall-oil-modified phthalic alkyds. Tall oil can also be utilized as a very low cost filtration agent; such an agent has possible applications for recovering the valuable but highly dilute constituents of industrial wastes which have been too expensive to extract. It has an important potential use in the recovery of minerals from low-grade ores (13, 30).

Literature Cited

1. Anonymous[3]. Synthetic oil from turpentine. Bus. Week, June 21, 1952. p. 45–46.
2. ———. Cashew nut shell binds pigments to fabrics. Sci. News Let. **62**(7): 105. 1952.
3. ———. Castor oil used in making oilcloth. Chem. & Eng. News **30**(28): 2918. 1952.
4. ———. New Indian oil source discussed. Chem. & Eng. News **30**(14): 1432. 1952.
5. ———. New chemical from trees may replace gum arabic. Chem. & Eng. News **30**(19): 1980. 1952.
6. ———. Grapeseed oil. Paint, Oil & Chem. Rev. **115**(2): 35. 1952.
7. ———. Indian chemists tell of quick drying paint oil. Paint, Oil & Chem. Rev. **115**(1): 13. 1952.
8. ———. Oils and fats in India. Oil, Paint & Drug Rep. **161**(16): 38. 1952.
9. ———. Coconut substitutes. Soap & San. Chem. **28**(4): 95. 1952.
10. ———. Seaweed derivative considered as talcum powder ingredient. Amer. Perf. & Ess. Oil Rev. **59**(2): 135. 1952.
11. ———. Wood gum vs. arabic. Chem. Week **69**(4): 21. 1951.
12. ———. New naval stores boost. Chem. Week **70**(8): 31. 1952.
13. ———. Tall oil in flotation processes. Naval Stores Rev. **62**(33): 16–18. 1952. [Reprinted, without author's name or other data, from Tall Oil Bulletin].
14. ———. U.S.D.A. research develops new chemical from turpentine. Amer. Paint Jour. **36**: 80. 1952.
15. ———. Oil, Paint & Drug Rep. **115**: 38. 1952.
16. ———. Paint M'f'r. **22**: 119–122. 1952.
17. ———. Paint M'f'r. **22**: 403–406. 1952.
18. ———. For. Comm. Week, Feb. 25, 1952. p. 18.

18*a*. ———. Cotton Gin & Oil Mill Press **53**: . 1951.

19. Batterson, V. C., and W. M. Potts. The analysis and characterization of the oil from the seed of *Stillingia sylvatica*. Jour. Amer. Oil Chem. Soc. **28**: 87–88. 1951. [Econ. Bot. **6**(1): 22. 1952].
20. Bolley, D. S., and R. H. McCormack. Mucilaginous materials from flaxseed. U. S. Patent 2,593,528. [Chem. Abst. **46**: 9333. 1952].
21. Bunger, W. B., and F. A. Kummerow. A comparison of several methods for the separation of unsaponifiable material from carnaúba and sorghum grain waxes. Jour. Amer. Oil Chem. Soc. **28**(3): 121–123. 1951.
23. Clagett, C. O., G. W. Hoffman and I. Sollen. Oil and protein content of sunflower seed. N. D. Agr. Exp. Sta., Bimon. Bull. **13**: 173–177. 1951. [Chem. Abst. **45**: 10424; Jour. Amer. Oil Chem. Soc. **29**(1): 74. 1952].
24. Kane, J. G. Indian Soap Jour. **17**(3): 72–74. 1951. [Soap & San. Chem. **28**(1): 79. 1952].
25. Kroner, A. A. What replacements for carnaúba wax? Soap & San. Chem. **27**(3): 110–113, 133. 1951.
26. Kummerov, F. A., H. N. Barham and H. H. King. An analysis of industrial uses of sorghum grain. Amer. Mill. & Proc. **75**: 94–95. 1947.
27. McIlroy, R. J. West African plant gums. Jour. Chem. Soc. **1952**: 1918–1919.
28. Markley, K. S. Glyceride oils and the Southwest. Chemurgic Digest **11**(3): 4–6. 1952.
29. Mueller, A. Grapeseed oil. Farbe und Lacke **57**: 240. 1951.
30. Perkins, K. A. Tall oil finds new uses in coatings. Chemurgic Digest **11**(11): 4–5. 1952.
31. Rhoades, W. F., and A. J. da Ville. Safflower oil polymerization. Jour. Amer. Oil Chem. Soc. **28**: 466. 1951. [Paint M'f'r. **22**: 225. 1952].
32. Sayre, J. E., and C. J. Marsel. The $100 million market for waxes. Chem. Week **71**(13): 29–36, 38, 41, 43, 45, 47, 49, 50. 1952.
33. Sharma, I. P. G., N. C. Budhraja and J. S. Aggarwal. Utilization of tobacco-seed and safflower-seed oils in varnishes and paints. Jour. Soc. Indian Res. **10*B***: 33. 1951. [Jour. Amer. Oil Chem. Soc. **29**(1): 38. 1952; Chem. Abst. **45**: 9278].
34. Shaw, A. C. Production of essential oils from coniferous foliage. Canad. Chem. & Proc. Ind. **35**: 44. 1951. [Econ. Bot. **6**(1): 17. 1952].
35. Steinle, J. V. Wax chemurgy in the U. S. Chemurgic Digest **11**(6): 4–5. 1952.
36. Taylor, K. W., and R. L. Chubb. Rubber recovery from freshly harvested guayule. Ind. & Eng. Chem. **44**(4): 879–882. 1952.
37. Waite, E. P., D. N. Collins and H. B. Summers. Promising new pine gum process. Chem. Eng. **59**(2): 199, 201. 1952.
38. Wells, P. A. Ten years progress at the four regional research laboratories. Chemurgic Digest **11**(4): 11–17. 1952.

[3] "Anonymous" in these citations refers to what presumably are editorial comments.

Recovery and Utilization of Tree Extractives

Tree species vary in properties because of the chemical nature of their respective extractive components. So it is that some species yield sufficient quantities of extractives to warrant their recovery for commercial uses. A number of such products, the most diversified of the forest products industries, is discussed here.

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INTRODUCTION

Trees are composed of a myriad of complex organic compounds. The most abundant constituent is cellulose, followed by lignin, hemicellulose and finally extractives, usually in that order. It is the last component which is under consideration here.

Extractives are those substances in trees and in the exudates therefrom which are soluble in neutral organic solvents or water. Extractives are distinguishable from the other components of the tree in that they are not an integral part of the cellular structure. When any part of a tree, whether it be the wood, bark, leaves or cones, is extract-free, the anatomical characteristics usually remain intact.

What type of materials make up the extractive components in trees? They may embrace practically all the various classes of compounds known to the organic chemist. Among them may be included hydrocarbons, alcohols, aldehydes, ketones, phenols, ethers, esters, lactones, oxides and acids. One or more of these functional groups may appear in any one of the compounds in a single extract. The elementary composition of these compounds involves carbon and hydrogen, with or without oxygen. Nitrogen in the form of proteins occurs

in the protoplasm, and some trees contain alkaloids. Thus it is apparent that a tree extractive component may be a simple organic compound or it may be of a most complex nature. Elucidation of the structure of many of these extractive constituents is attracting the attention of some of the foremost structural organic chemists in the world.

The type of extractive components present in any one tree species often determines its characteristics. Thus certain heartwoods are known for their durability against decay. Included among these are the redwoods, cedars and cypress. This particular ability to ward off wood-destroying fungi is attributable to the presence of fungicides in the extractives. Thus western red cedar (*Thuja plicata*) contains tropolones (thujaplicins) which are extremely toxic to wood-destroying fungi (15). And redwood (*Sequoia sempervirens*) contains tannins of the type which is thought to be responsible for the outstanding durability of this species. Certain heartwoods do not lend themselves to conventional methods of pulping. In pine heartwoods, for instance, the presence of a small amount of a dihydrophenol (pinosylvin) was found to act as an antipulping agent (16). Similarly dihydroquercitin is reported to be responsible for the antipulping property of Douglas fir heartwood (*Pseudotsuga taxifolia*) (51).

Thus it is that, since the chemical nature of some of the extractive components in various species and sub-genera is different, a thorough study of these components may reveal that one or more of these constituents may serve as a fingerprint for identification purposes. Some progress has been made in this direction. In a study of the volatile oils from oleoresin of various pines, Mirov has shown that species, closely related from the botanists' standpoint, are quite different when their volatile oils are carefully examined (44). Thus it was pointed out that, while it is difficult to differentiate morphologically between the white pines (*Pinus strobus* and *Pinus monticola*), the chemistry of each is quite different. The former contains *n*-undecane, while this hydrocarbon is not present in the latter. Similarly identification of the constituents in the volatile oils from the closely related pines *Pinus ponderosa* and *Pinus jeffreyi* offers a key to the taxonomist for identification purposes. The volatile oil from ponderosa pine is terpenic in nature, while that obtained from Jeffrey pine is aliphatic in composition, the predominating component being *n*-heptane. The brilliant studies by Erdtman and his coworkers in Sweden on the nature of some of the extractive components in pine heartwoods have been of considerable taxonomic value. Of the seven species belonging to the Haploxylon (mostly five needles) sub-genera investigated, all contain the cyclitol, pinitol, while none has been found in the eleven Diploxylon species (two or three needles) thus far examined (17). Still other extractive components which distinguish these two sub-genera are the flavones, chrysin and tectochrysin, that occur only in the Haploxylon series. Thus, while the chemist has been able to offer some chemical data to aid the taxonomist, the extractives from many more species must be thoroughly and carefully examined before the chemist can throw more light on the questionable aspects of taxonomy.

Just as extractive components often serve to characterize a wood, the amount and type of extractives in various species have more or less determined which species are suitable as raw material for commercial production of chemical products. Some of the tree species which are used for that purpose will be discussed here. This is not intended to be a complete review, but rather to point out some of the more important commercial

practices which recover and use tree extractives.

PINE TREE RESINS AND TURPENTINE

In the commercial production of extractives from southern pine trees, four methods are employed in this country: *a*) collection of oleoresin from living trees; *b*) solvent extraction of pine stump wood; *c*) recovery of tall oil and turpentine from the sulfate pulping process; *d*) destructive distillation of wood. All these industries, in the main, are confined to the southeastern gulf States, principally because southern pines, largely longleaf (*Pinus palustris*) and slash (*Pinus caribaea*), are the richest source materials for these products. The average annual value of these combined pine extractive products gives them a foremost place among southern industries.

Rosin and Turpentine from Oleoresin

One of the first industries started in this country by the early settlers was the collection of exudates from pine trees. This commodity was of considerable importance, for it was used in treating rigging and caulking the joints of wooden ships. This exudate product was known as "naval stores", and the term is still used.

In the early days a deep box was cut into the base of the tree to receive the oleoresin which exuded from the subsequent cuts made directly above the deep wound. When the oleoresin flow ceased, another fresh cut was made, and thus the tree was induced to produce more exudate. This early turpentining practice caused a high fatality among trees, since they were subject to wind fall. Hence, gradually, improvements were made. In recent years, particularly by the Naval Stores Division of the U. S. Department of Agriculture, the turpentining techniques have been improved, resulting not only in prolongation of the useful life of the tree but also in greater yields of oleoresin. The oleoresin products are known as "gum rosin" and "gum turpentine", to distinguish them from the rosin and turpentine obtained by other methods.

The term "gum" to describe these particular products perhaps is somewhat ambiguous. While it is known that tree gums are exudates, as is the oleoresin from which these products are derived, a true tree gum is a polysaccharide which is either completely or colloidally soluble in water (31). Pine oleoresin, on the other hand, is insoluble in water and the constituents are largely terpenic in nature. Thus "gum" is not truly descriptive for the rosin and turpentine obtained from oleoresin. A term such as "oleo-rosin" and "oleo-turpentine" would perhaps be more appropriate.

In present recommended practices, only trees exceeding nine inches in diameter are turpentined (6). First, an area of the bark near the base of the tree is shaved off, after which a shallow cut is made a few inches above the ground and an apron or gutter is inserted. A cup of one or two quart capacity is placed so as to collect the oleoresin drippings. A shallow streak, about one-half inch deep, is cut with a "hack" above the gutter. Oleoresin soon appears from the wounded area and flows into the cup. During the turpentining season from March through October, a "chipper" usually makes weekly rounds to each cupped tree and freshens each working face by chipping a new shallow streak. Each tree during a season will produce a yield of about eight or nine pounds of crude oleoresin.

After three or four seasons the regular streaking raises the top level of the face to shoulder height, and from that time on, the chipper uses a longer instrument to make the streaks. And the cups and gutters are lifted to the height of the "catface" advances to avoid de-

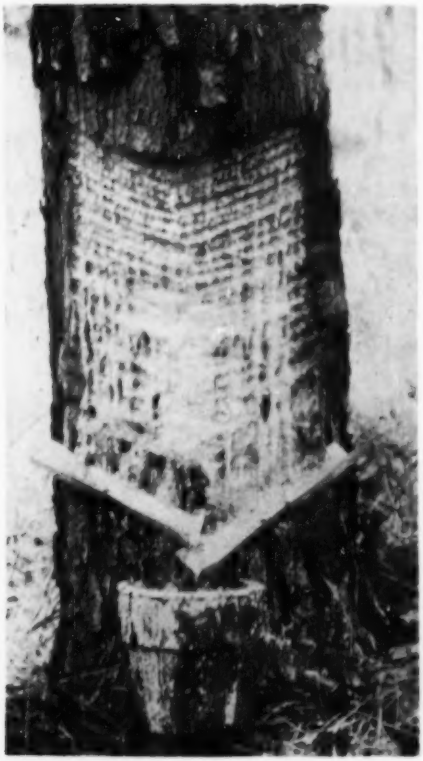

FIG. 1. Pine tree being worked for naval stores, using the conventional hack for chipping the tree. (*Courtesy U. S. Dept. Agr., Naval Stores Station.*)

terioration of the oleoresin due to flow over a large area before collecting in the cup. When the top of the face is no longer readily reached, the tree is usually allowed to rest for several years before opening a new face on the opposite side.

A recent development has occurred in the turpentining industry to improve oleoresin yield. This is the acid-treatment of turpentine streaks. It has been shown that periodic chipping in two- to three-week intervals and simultaneous treatment with 60 percent sulfuric acid resulted in an average yield increase of 68 percent of total oleoresin production for the season (13, 14). Further, the latest development, one already accepted by more than one-quarter of the industry, is bark chipping and acid-treatment (52). In the newer method, faces are freshened by removal of a five-eighth-inch wide strip of bark. No wood is removed. The fresh streak is sprayed with 50 percent solution of sulfuric acid. Streaks, so treated, produce 50 to 100 percent more oleoresin during the first week and continue to yield above normal quantities during the second and third weeks after bark-chipping. Thus the interval of chipping can be increased from the usual one week to two or three weeks, resulting in less scarification of the tree and less labor with no decrease in oleoresin yield. This latest technique also leaves the base of the tree in much better condition for subsequent utilization, such as for pulpwood or lumber.

Still another recent turpentining method has been suggested. This is based on the discovery that a certain fungus, a form of *Fusarium*, when inoculated in the trunks of conifers, results in a high yield of a continuous flow of oleoresin without need of repeated chipping (28). Sufficient time has not yet elapsed to appraise this oleoresin stimulation method for commercial purposes.

Processing of Pine Oleoresin. In the early days each operator processed his oleoresin. The crude exudate was poured into direct fired iron kettles, and the batch distillation carried out through iron coils to condense and collect the turpentine. When the volatiles no longer came over, the rosin was allowed to run into open barrels. Later water was added to the oleoresin in copper stills to effect steam distillation. The turpentine distillate was separated from the water. When only a small amount of turpentine came over, addition of water to the still was discontinued and the temperature raised a little—then the

still was drained and the hot rosin strained through cotton on screen filters before running into barrels.

In the past 15 years, fire stills have been largely replaced by central distilling plants using steam (7). The oleoresin is generally cleaned before distillation by washing with water, turpentine is added to decrease the viscosity, and then it is filtered. Finally the turpentine is separated from the resinous portion by steam distillation in stainless steel batch stills.

A more recent processing technique has been developed involving a continuous flash still (21). Here the previously cleaned oleoresin is diluted with turpentine, is preheated and led into a flash chamber where about 80% of the turpentine is immediately vaporized. The hot rosin flows down into a heated stripping column having steam jets near the bottom. The small amount of remaining turpentine is stripped from the rosin, and the turpentine-free rosin is drawn off at the bottom directly into drums. The flashed turpentine vapor is condensed, the turpentine is dehydrated and pumped into storage. This newest process, which was largely developed by the Naval Stores Division, U.S.D.A., holds promise of improving the competitive position of the oleoresin naval stores industry.

The ratio of oleoresin rosin to turpentine is about 2.7 drums (520 lb. net each) to 50 gallons (one barrel) of turpentine. The amount of oleoresin turpentine produced in this country in the years 1940–1950 varied between a low of 244,000 barrels in 1945 and 344,000 barrels in 1940 (8). During the same period the production of oleoresin rosin was 692,000 to 939,000 drums. The peak production of these products was during the first 15 years of this century, amounting to about twice the quantity produced annually during the last few years. This drop in production occurred when other processes for obtaining turpentine and rosin were being introduced in this country, notably the wood rosin industry.

Currently naval stores are obtained from pine forests covering 30,000,000 acres, principally in northern Florida and the southern area of Georgia, Alabama, Mississippi and Louisiana. Georgia and Florida produce more than 90% of the domestic naval stores (56).

Other countries also produce naval stores. Some of these are listed in Table I (6, 57).

TABLE I

SOME FOREIGN COUNTRIES PRODUCING TURPENTINE AND ROSIN (OLEORESIN)

Country	Species	
France and Spain	*P. maritima* syn. *P. pinaster*	Maritime or cluster pine
Greece	*P. halepensis*	Aleppo pine
Russia	*P. sylvestris*	Scot's pine
India	*P. roxburghii* syn. *P. longifolia*	Chir or chil pine
Indonesia	*P. merkusii*	Mindero pine
Mexico	*P. arizonica*	Arizona pine
	P. chihuahuana	Chihuahua pine
	P. teocote macrocarpa	Jalocote
	P. montezuma	Montezuma pine

Composition and Use of Turpentine and Rosin. American turpentine is a relatively simple mixture of about two-thirds α-pinene and one-third β-pinene. Turpentine finds wide use in the chemicals and pharmaceutical fields. It is utilized as a thinner for paints and varnishes; also for making ester gums and synthetic resins. Synthetic camphor is produced from α-pinene. It is also used in waxes, shoe dressings, oil additives and in foundries.

The chemical composition of rosin, from both oleoresin and wood, is given in Table II (27).

The major uses of rosin, from both oleoresin and wood, are as a paper size;

TABLE II

COMPOSITION OF ROSIN

Fraction	Percent
Neutral	10
Abietic-type acids	53
Dihydroabietic acid	11
Tetrahydroabietic acid	18
Dehydroabietic acid	3
Oxidized acids	5

in protective coatings, such as varnishes, enamels and paints; in chemicals and pharmaceuticals; and in yellow laundry soap. Minor uses include adhesives and plastics, linoleum and floor coverings, oils and greases, paint dryers, rubber compounding materials, and printing inks.

Wood Rosin and Turpentine

The oleoresin industry was the major source of rosin and turpentine until about 1910. At the height of this industry's production it was prophesied that the naval stores industry would soon decline because of the gradual depletion of virgin pine forests. This prophecy was soon to be proven erroneous, by the self-seeding of the rapidly growing pines in cut-over areas, as well as by improved techniques developed for procuring oleoresin. In any case this assumption initiated what is now known as the wood naval stores industry, i.e., the recovery of rosin, pine oil and turpentine from southern pine stump wood as distinguished from naval stores obtained from living trees.

Large-scale harvesting of trees for lumber in the southern States left millions of acres of cut-over areas containing pine stumps. These stumps were rich in extractive content, and the initial efforts to steam distill the comminuted stump wood only for recovery of turpentine and pine oil proved to be economically unsound. The yield of the steam-volatile constituents amounted to about five percent and left about 20% unrecovered resin in the spent stump wood. It was not until subsequent solvent extraction of the wood to recover the non-volatile resinous extract that the wood rosin industry become established as a successful commercial enterprise.

The first successful commercial operation, called the "steam and solvent process", was pioneered by H. T. Yarayan in 1909 at Gulfport, Mississippi, producing some 14,300 barrels of rosin, together with turpentine and pine oil, during its first year of operation (33). Forty years later this yearly output increased to about 1,100,000 drums (520 lbs. net, each) of rosin and 200,000 barrels (50 gals. net, each) of volatile oils (8).

Processing Wood Rosin and Turpentine. The practice of the wood rosin-processing industry is to allow stumps to remain in the ground ten years or so before they are harvested. During this interval, the bark and sapwood, which are low in resin content, usually separate from the stump, leaving stump heartwood intact which is rich in resin content. The stump heartwood contains approximately 18% water, five percent terpene oils, 22% rosin, and about four percent gasoline-insoluble resene (33).

Various methods are used for removing the stumps, such as dynamite, diesel tractors and stump-pulling cranes. If the stump is large, it is often split and put into gondolas or trucks along with the roots and any other resinous wood which happens to be available. When the material reaches the processing plant, it is either dumped into stock piles or immediately conducted to the mill for processing. Here the stump wood is carried on a conveyor where the wood is washed with water under pressure to remove gravel, dirt and other foreign matter. Next it is put into a mechanical hog which reduces the wood to chips, which in turn are shredded by hammer

mills to splinter-type chips suitable for extraction.

The comminuted wood is run into a series of vertical towers about 24 feet high, each having a capacity of 13 to 15 tons of chips. A hot solvent, such as a petroleum fraction or benzene, is pumped under pressure into the bottom of the first extractor and passes countercurrently through the remaining extractors which are kept at 65 to 85 p.s.i. gauge pressure. Fresh solvent is always changed to the vessel containing the most nearly exhausted chips. After the extraction period, the exhausted chips are steamed to recover the solvent, and then dumped to be used usually as fuel. One company is using these spent chips for making fiber board (45).

The solvent containing the extract is sent to an evaporator to recover most of the solvent, the remaining solvent being recovered in a flash tower. The effluent here is pumped to towers where steam strips the terpene oils from the rosin under vacuum. The terpene oils are washed with dilute caustic solution to remove aldehydes and improve odor. The oils are then fractioned into turpentine, intermediate terpene and pine oil fractions. The hot stripped crude rosin is run off into drums.

This crude rosin, known as FF rosin, is dark-red, differing considerably from the conventional yellow to brown grades of oleoresin rosin. Further, unrefined wood rosin acquires objectionable color upon aging, which it imparts to soaps, ester gums and varnishes, whereas oleoresin rosin is more color-stable and hence has enjoyed a wider market. Until properly refined, crude wood rosin was forced to remain in the lower priced rosin market, with outlets chiefly in linoleum, core oils and the darker sized grades of paper.

Many attempts were made to refine wood rosin to the paler grades before commercially successful methods were finally developed. Two commercial processes are now used in refining wood rosin, namely, adsorption earth refining with Fuller's earth and selective solvent refining with furfural.

In the adsorption earth refining process, the crude dark colored FF rosin is dissolved in petroleum naphtha to make up a 15 to 20% solution, washed with water to coagulate any suspended insolubles and then allowed to stand until all water has settled (45). The rosin solution is then passed through a series of columns containing the earth. The resin is continuously adsorbed and eluted, whereas the color bodies and other impurities are retained on the adsorbent. After the earth becomes saturated with impurities, it undergoes a revivification treatment. When the adsorbtion tower is cut out of the decolorization cycle, it is full of rosin solution. The solution is first displaced with warm naphtha, the displacement going into the tower following in the cycle. The naphtha is then displaced with just sufficient alcohol-naphtha (35% alcohol by volume) to fill the column, the solvent being introduced through a preheater. The extraction of absorbed pigment is rapid and complete, so that introduction of the revivification solvent is immediately followed by boiling naphtha to wash out the revivification solvent now containing the color bodies which have been removed from the earth. The solvents are recovered and the impurities recovered as dark resin. The decolorized rosin is obtained by evaporating the solvent from the column eluant. The grade or degree of purification desired is controlled by the amount of rosin solution passed through the earth.

In the selective solvent refining procedure, wood rosin is fractionated by mixing it intimately with two substantially immiscible liquids, one of which preferentially dissolves its color-bearing components and leaves the purified rosin

FIG. 2. Turpentining using the bark hack and acid stimulation method. *(Courtesy U. S. Dept. Agr., Naval Stores Division.)*

in the other liquid phase (33). Wood rosin is purified commercially in a continuous process by washing with a countercurrent flow of furfural in a refining tower. The tower is about 40 feet tall and three feet in diameter. It contains a series of plates, and a 15% crude rosin in petroleum naphtha solution is pumped into the bottom of the tower, while furfural is fed into the top. The higher specific gravity furfural moves downward through the rising resin-naphtha

solution, in each of the separate trays. The refined rosin solution is drawn from the top of the tower, while the highly colored furfural solution, containing the color bodies, is drained from the bottom. The petroleum naphtha is distilled from the refined rosin by passage through a series of evaporators. The refining process is quite flexible in that rosin of various grades can be obtained. The furfural is recovered by distillation, leaving a dark resin known as "Vinsol".

Production of wood rosin and turpentine has gradually increased since the industry started in 1910. In 1949, 1,099,000 drums (520 lbs. net, each) of rosin and 200,000 barrels (50 gallons each) of turpentine were produced (8). This amount of production required about 1,300,000 tons of stumpwood, obtained from around 430,000 acres or so of cut-over area.

Composition and Use of Wood Turpentine and Pine Oil. Wood turpentine contains about 80% α-pinene and a little β-pinene. The pine oil fraction is a complex mixture of terpene hydrocarbons, aldehydes, alcohols, ethers, ketones and phenols.

Pine oil has diversified uses in the textile industry as a penetrant, dispersing agent, wetting agent, an inhibitor of bacterial growth in practically all wet processing of cotton, silk, rayon and woolen goods, including scouring, bleaching, desizing and degumming. In the paper industry it is used as a wetting and leveling agent in coating, as a preservative of casein and as a foam breaker. Minor uses are in cutting oils, floor oils, polishes, printing inks, liniment, odorant block, cattle and other insecticidal preparations.

Sulfate Turpentine and Tall Oil

These extractives are by-products obtained from the sulfate pulping process of pines. These products were first produced in the Scandinavian countries since the early part of the present century, but not in this country to any extent until the 1930's. However, sulfate turpentine has had a rather remarkable growth, for, while only 4,000 barrels were produced in 1930 in this country, in 1949 production reached 148,000 barrels (50 gallons net, each), amounting to little over 40% of the total wood turpentine produced in 1949 (8) or nearly one-fourth of the total turpentine production in the United States.

Sulfate turpentine is recovered in the pulp mills by condensing the vapor relieved during the cooking of pine chips. Longleaf and slash pine pulpwood yield 2.8 to 4.3 gallons of crude turpentine per ton of air-dry pulp; loblolly, shortleaf and Virginia pine yield 2.5 to 2.7 gallons per ton; jack pine and white pine yield 1.5 to 3.1 gallons per ton (34). The crude turpentine, so recovered, has an objectionable odor because of the sulfur compounds evolved during the cooking process. Three methods are employed in deodorizing sulfate turpentine: *a*) distilling and washing with bleaching powder; *b*) treating with hydrogen and treating the distilled product with calcium chloride and activated carbon; *c*) air-oxidizing the mixture and then steam distilling. The turpentine contains 50 to 60% α-pinene, 20% β-pinene, and other terpene hydrocarbons. This refined sulfate turpentine finds the same markets as does turpentine from other sources.

The alkaline medium employed in the soda and sulfate pulping process saponifies and dissolves the 4% to 5% resins in the wood chips. Thus this product is in the form of sodium salts dissolved in the waste black liquor. On cooling or concentrating the liquor, the soap skimmings separate and are washed free of suspended black liquor by dissolving in hot water and precipitating by addition of salts. Acidification with mineral acid regenerates the resin-fatty acids which,

FIG. 3 (*Upper*). Conventional fire still formerly used for the batch distillation of crude pine oleoresin. These stills are now obsolete and practically extinct. (*Courtesy U. S. Dept. Agr., Naval Stores Division.*)

FIG. 4 (*Lower*). A modern central distillation plant using the Olustee system for oleoresin cleaning and distillation. (*Courtesy U. S. Dept. Agr., Naval Stores Division.*)

with some neutral material, are separated by centrifuging or settling.

Typical analyses of the crude tall oil may range from 40% to 50% each of resin acids and fatty acids, and 10% neutral material. The composition of the resin acids in tall oil is comparable to that found in wood rosin. The fatty acids are composed essentially of oleic and linoleic acids, with some linolenic and palmitic acids. The neutral fraction contains the plant sterol, β-sitosterol, and it has been isolated on a commercial scale.

Crude tall oil is colored and has an objectionable odor, so most of it is refined. Acid-washing and vacuum distillation are the more common methods used, while selective solvent and adsorption earth refining are employed to a lesser degree. The refined tall oil is used extensively in metal polishes, horticultural sprays, textile lubricants, paper sizing and soap. The 1949 production of tall oil amounted to 191,000 drums (520 lbs. net, each) (8).

Destructively Distilled Turpentine

Destructive distillation of resinous wood has been carried out many centuries. The turpentine and pine oils are removed from the retort before the temperature is attained at which the resin acids and wood begin to decompose. However, this is relatively a small industry. In 1949 only 3,000 barrels of destructively distilled turpentine were produced, less than 0.5% of the total turpentine production that year (8).

TANNINS AND DYES

The bark or wood of certain tree species, when leached with hot water, will produce an aqueous extract which has an astringent taste, produces a dark blue or green coloration with ferric salts, precipitates gelatins, soluble proteins and alkaloids from solution, and combines with skin protein to form leather. Such substances are referred to as natural or vegetable tannins.

For many years tannins were grouped under two general headings: *a*) catechols, consisting of the tannins from quebracho and wattle woods and of hemlock bark; and *b*) pyrogallols, comprising the tannins from chestnut wood, sumach and myrobalan. This system has only limited value. In view of the amorphous nature of tannins, the difficulty of purification and the diversity of substances which act as tanning agents, it is not surprising that determination of the chemical structures has proved to be not only difficult but highly uncertain. They are known to consist, in part, of complex polyhydric phenols.

Several methods of classifying have been proposed. One of the later systems is that proposed by Freudenberg, in which the tannins are divided into two main groups as follows (22).

a) Hydrolyzable tannins—those that can be hydrolyzed by acids and enzymes, such as the glucosidic chestnut tannin.

b) Condensed tannins—those that cannot be hydrolyzed by acids and enzymes, such as tannins from quebracho and oak (phlobatannin).

Tannin Sources (9, 11)

While many tree species contain tannin, relatively few are used as commercial sources of tanin. In this country the main domestic supply comes from chestnut wood (*Castanea dentata* Borkh). However, this source has been essentially eliminated, since the chestnut

FIG. 5 (*Upper*). Harvesting old southern pine stumps for extraction with bulldozer in young pine forest. (*Courtesy Newport Industries, Inc.*)

FIG. 6 (*Lower*). Shredder reducing stumpwood for use in extractor. (*Courtesy Hercules Powder Co.*)

blight has killed most of the trees and threatens to exterminate the species in the United States. The two domestic sources next in order are eastern hemlock bark (*Tsuga canadensis* Carr) and chestnut oak bark (*Quercus montana* Wild). The barks of two additional species are also used in tanning in the Pacific Coast region, namely tanoak (*Lithocarpus densiflorus* Rehder) and Douglas fir (*Pseudotsuga taxifolia* Britton).

The United States is a heavy consumer of tannin, and the present domestic sources are not adequate to supply the demand. Hence, much of it is imported. The main source of imported tannin is quebracho wood (*Schenopsis lorentzii* Engl.) obtained from Argentina and Paraguay. Additional tanin comes from Borneo and South Africa. A partial list of the main sources is given in Table III (19).

TABLE III

SOME TANNIN SOURCES

Tannin	Species	Part of Tree	Tannin, Percent	Source	U. S. Consumption, 1945, Percent
Quebracho	*Schenopsis lorentzii* Engl.	Wood	20	South America	44.5
Chestnut	*Castanea dentata* Borkh	Wood	9	United States	31.2
Mangrove	*Rhizophora mangle* L.	Bark	34	Borneo	5.6
Wattle	*Acacia pycnantha* Berth	Bark	36	South Africa	4.0
Oak	*Quercus prinus*	Bark	11	United States	1.8
Hemlock	*Tsuga canadensis* Carr	Bark	11	United States	1.2
Miscellaneous	.....	.....	..	.....	11.7
					100.0

Thus, it will be noted, the United States had to import two-thirds of its tannin requirement in 1945, a sizable amount, since 194,000,000 lbs. (100% tannin) of vegetable tannins were consumed by the tanners in this country that year (20). It is apparent, therefore, that new sources of tannin are needed. Various sources of potential tannin are the barks from western hemlock (*Tsuga heterophylla*) and mangrove (*Rhizophora mangle* L.) and expansion in the use of Douglas fir bark.

Extraction of Tannin

Bark for tannin-extract manufacture is usually peeled in the woods, cut into four-foot lengths, piled and air-dried before sale (46). Before a tree is felled, two girdling rings are cut around the butt, one near the ground and the other four feet above. The bark is split vertically, then peeled off with axes or spuds. The first ring of bark is removed from the standing tree to prevent loss of valuable bark when making the undercut for felling and because it is more easily removed while the tree is erect. After the tree is felled, girdling rings are cut at four-foot intervals along the bole and the remaining bark is removed. As each ring or coil of bark is removed, it is exposed, preferably, to the sun and wind to obtain rapid drying for mold prevention. This preliminary drying is allowed to continue for several days, then the bark is gathered and piled on pole skids and allowed to season for two to three months. In eastern hemlock and oak stands, two-man crews can collect two to three cords of bark per day, weighing between 4500 and 7000 lbs. In the tanoak region on the Pacific Coast, because of larger trees, about twice as much bark can be collected by two-man crews per

day. The peeling season usually begins in May and ends in August for all regions.

In preparing the harvested bark for extraction, it is reduced to suitable size by putting it through shredders. In the case of wood, it is put through chippers similar to those used in paper-pulp manufacture, and then further reduced in shredding mills.

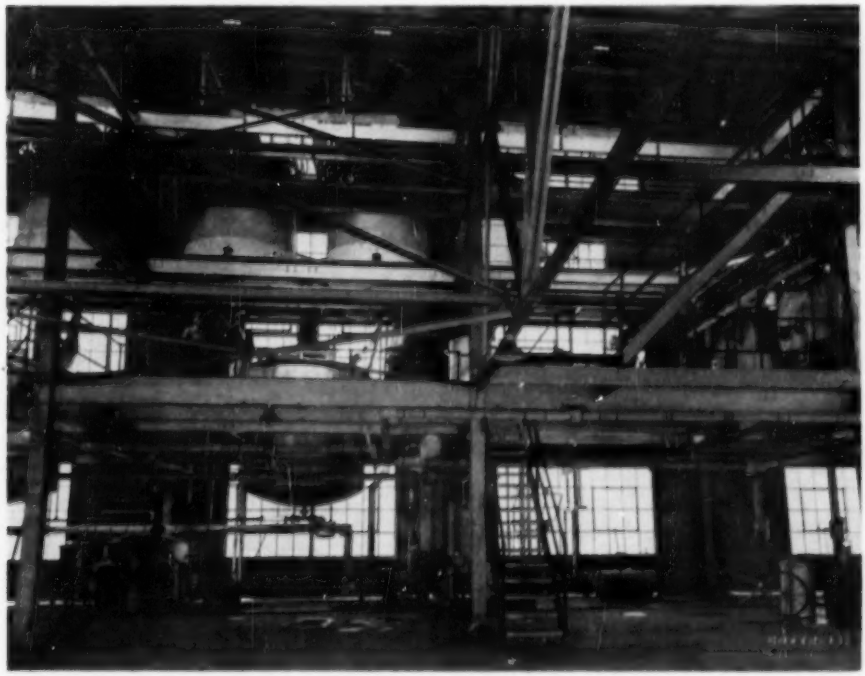

FIG. 7. View in processing building where purified rosin is treated chemically to make specialty products. (*Courtesy Newport Industries, Inc.*)

There are four methods in use for extracting tannin: *a*) open-tank diffusion, *b*) percolation, *c*) decoction, *d*) autoclave (9). The first two are usually used in extracting barks, while the latter two are generally employed to extract tannin from wood.

In the open-tank diffusion method wooden tanks 12 to 14 feet in diameter and 12 to 16 feet in height are filled with shredded bark. The liquor is heated by steam coils or perforated pipes under the false bottom of each extractor. When direct steam is used, allowance for dilution resulting from condensation of steam must be made in the quantity of weakest or "tail" liquor introduced. The liquor is continuously pumped forward through a multiple number of vessels or "leaches". The fresh water enters at one end of the battery and the leached product leaves the last vessel, known as the "tail" unit. The strong liquor is obtained from the vessel containing fresh wood, and the number of washings as well as the number of units used is determined by the operator. This process requires from two to four

days for an extraction. For barks yielding condensed tannins, as are obtained from chestnut oak and eastern hemlock barks, it is especially desirable to keep the temperature of the water below the boiling point because boiling enhances the formation of "insoluble reds", with a consequent loss of tannin and a darkening of color.

In the percolation method the bark in the extractor is first steamed, using a perforated steam pipe in the bottom of the extractor. This causes the chips to settle uniformly and compactly. Hot water is then sprayed on the bark from the top at the rate of about two and one-half gallons per hour per square foot of area with a 12-foot column of bark. The resulting liquor is drawn off at the bottom of the extractor. From 24 to 36 hours are required to complete the extraction.

The decoction method consists of boiling the wood chips immersed in water. This process is also carried on in batteries of "leaches". In practice a leach is filled with nearly saturated liquor, heated, and the wood kept immersed until the strongest saturation of the liquor is attained, after which the extractor is drained and refilled with a weaker solution from the preceding extractor. The time for extraction in this process is about one day.

Although quebracho heartwood yields a condensed tannin, the wood is extracted by the decoction method. To overcome the undesirable formation of water-insoluble reds, the liquor is treated with sodium sulfite or some other sulfite in the last stage of extraction (46). The sulfite treatment dissolves the reds and difficulty soluble tannins, keeping them soluble in cold water and in the acidulated liquor of the tanning vat, and preventing their precipitation in sour liquor, thereby saving and utilizing tannins that otherwise would be precipitated and regarded as waste. While normally only the heartwood is used in extracting tannin, recent experimental studies have indicated that the yield of quebracho extract can be appreciably increased by processing the entire trunk instead of only the heartwood (53).

In this country the larger plants extract American chestnut wood at temperatures above the boiling point of water, in copper autoclaves operating under pressure up to two atmospheres (9). Each battery contains eight units, each holding one and one-half cords of shredded wood. The tail unit is cut out of the battery for discharge, as well as one unit for refilling, so that six are constantly used. The autoclaves have a full drop bottom operated by hydraulic cylinders, so arranged that the operator on the top platform can control the full operation. The discharging and filling cycle requires only about three minutes. The economy of this process lies in the lesser quantity of water required (297 gallons per ton of wood), the shorter extraction time (45 minutes) and the better quality of tannin produced. The spent chestnut wood has been used in the manufacture of paper and fiberboard. This is a good example of the desirability of integrating extraction with other wood-utilization methods, for, although the tannin content of the wood is only six to ten percent, the extraction has proved profitable because the extracted chips find an outlet in another wood utilization process.

After the tan liquor is obtained from the extractors it is next concentrated to the desired density or concentration. The final concentrations fall into three classes: liquid, containing 25–35 percent tannin; solid, containing 40–65 percent tannin; and powdered, containing 55–70 percent tannin.

In the production of liquid extracts, the liquor is evaporated, usually in a vacuum evaporator, until it reaches the

FIG. 8. Tanbark oak in the redwood forest of California, one source of bark tannin used in the manufacture of leather. (*Courtesy The Timberman.*)

proper consistency. The vacuum evaporator may be of single, double, triple or even quadruple effect. The cooled concentrated extract for shipment is pumped into tank cars lined with a paste of red lead and linseed oil or with special coatings to protect the iron from corrosion and to prevent extract discoloration that results from contact with iron. If solid extract is desired, evaporation is continued until the concentrate is thick enough to be run into paper-lined sacks or into casks, where, on cooling, it solidifies into an amorphous and brittle product containing about 20 percent moisture. Another method employed in making powdered extract is to place the liquor concentrate in a vacuum drum drier to reduce it to a powder containing about five percent moisture. Another method is to atomize preheated tan liquid into a drying chamber, where the excess water is evaporated by a circulating air stream. It is reported that spray drying gives the better product (46).

In all extraction processes for tannins, materials other than tannins are extracted simultaneously. Hot water dissolves substances which are insoluble in water at room temperature (11). These substances are referred to as insolubles or "phlobaphenes". In addition, water-soluble substances not fixed by hide substance accompany the tannin. These substances, called "non-tannins", may consist of free sugars, simple acids, inorganic salts and phenolic components which are not absorbed by the hide protein. The crude tannin extracts are used technically with little or no purification.

Uses of Tannin

In addition to the use of tannins in producing heavy leathers, about 40 percent of the total tannin consumed in the United States is used to control the viscosity of the mud in oil-well drilling (46). Tannin is employed also in the manufacture of iron gallotannate ink, by combining iron and tannin. Smaller quantities are used in the flotation of certain ores, as antioxidants in edible fats, and as medical astringents.

Dyes (12, 47)

While some years ago natural dyes were the only means of coloring fabrics, today the cheap and varied aniline dyes have almost completely supplanted the natural dyes. Only a few natural dyes are still used, among them being several products of the forest. Several of these tree dyes will be briefly described to illustrate this type of forest product extract.

One of the most important wood dyes is that obtained from logwood (*Haematoxylon campechianum*) which is extracted with water in autoclaves under 80 pounds pressure. This tree is indigenous to the West Indies, Central America and the warmer parts of South America. The coloring principle is a compound called "haematoxylin" which, when oxidized, produces the actual dye, haematine. Depending on the type of mordant applied, the color imparted to fabrics ranges from blue to black.

The wood of Cuba or yellowwood (*Chlorophora tinctoria*) which produces a yellow dyestuff, maclurin, is a native of Brazil, Mexico and the West Indies. The dye, known also as "old fustic", is used principally for dyeing leather and wool. The olive shades produced are particularly adapted for dyeing khaki cloth, and for this reason it is able to retain a place of some importance in the world's dyestuff commerce.

Quercitron bark is obtained from the inner bark of the native black oak (*Quercus velutina*). It contains quercitrin, which is a glycoside of quercetin. Rutin, one of the glycosides of quercetin, has attracted wide interest because of its vitamin activity. Bark extracts of quercitron are used in cotton and wool printing, producing yellow color comparable to that provided by old fustic.

FIG. 9. Tanbark oak trees are cut so they do not lay on ground to facilitate peeling. Season runs from May to August. (*Courtesy The Timberman.*)

VOLATILE OILS

Volatile oils are common constituents of many plants distributed throughout the plant kingdom. And there are a number of tree species whose leaves, bark and wood serve as sources for the production of aromatic and essential oils. These oils are usually recovered by steam distillation of the comminuted product either at atmospheric or high pressures. The distillate is collected and the volatile oil separated from the aqueous phase. Some of the oils are used as recovered, while others are submitted to fractional distillation to recover various fractions or pure compounds.

The largest volatile oil industry is, of course, the recovery of turpentine and pine oils from southern pines which was discussed previously. In addition, vola-

tile oils are also recovered in this country from cedar-wood, conifer leaves, sweet-birch bark, and sassafras root and bark.

Cedar-wood

One of the principle sources of cedar-wood oil is the wood residue resulting from products manufactured from eastern red cedar (*Juniperus virginiana*) (35). The oil yield varies from one to three percent, depending on the proportion of heartwood present in the material being distilled. Production is mostly in Virginia, North Carolina and Tennessee. Total annual production is about 300,000 pounds. The principal constituents in the oil are sesquiterpenes, namely, cedrene, a hydrocarbon, and the alcohols, cedrenol and cedrol. It is used in the manufacture of soaps, furniture polish, sanitary supplies and perfumes. Because of its high index of refraction, the refined oil is used in oil immersion microscopy.

During the last war cedar-wood oil was also obtained from *Juniperus mexicana* in Texas (35). In this instance the entire log was chipped and subjected to steam distillation for recovery of the oil—the oil being the sole product recovered. About 150,000 lbs. of oil were produced annually. The composition and use of this oil are comparable to those of eastern red cedar.

Conifer-leaf

The leaves from a number of conifers are used in the production of leaf oils. These include black spruce (*Picea mariana*), white spruce (*Picea canadensis*), eastern hemlock (*Tsuga canadensis*) and red cedar (*Juniperus virginiana*) (54). The oils obtained from spruce and hemlock are so similar that no attempt is made to keep them separate. The oil yields are from 0.1 to 0.6 percent. The main constituents are borneol and borneol acetate. Production is confined to the New England States and is usually carried out by farmers in the winter time when work is slack. About 50,000 pounds of oil are produced annually in the United States. The major uses of this oil are for ointments, liniments, bath salts, soaps and shoe polishes.

Sweet-birch

This oil is prepared from the bark of sweet-birch (*Betula lenta*) and is very much like oil of wintergreen (54). The main constituent is methyl salicylate. Most of the oil is produced in Connecticut and Tennessee. After the bark is chipped, it is steeped in warm water for 12 hours or so, then steam-distilled. It is reported that the methyl salicylate in the oil is produced by enzymatic action during the steeping period. About five pounds of oil are produced per ton of bark chips. The oil is used as a flavoring agent for drugs and candies.

Sassafras

Sassafras oil is obtained from the tap root, stump and bark of the sassafras tree (*Sassafras albidum*) (54). These trees grow in Tennessee, Maryland and Virginia. The trees are uprooted by bulldozers and the tap roots and stumps are hogged and chipped preparatory to steam distillation. The root bark contains about nine percent oil, while the wood has about one percent. The major constituent is safrole, with smaller amounts of α-pinene, phellandrene, camphor and eugenol. The oil is chiefly used as the flavor in carbonated beverages, dentifrices and medicinals. Annual production in the United States is 150,000 to 200,000 pounds.

Eucalyptus (24)

There are over 500 species of the genus *Eucalyptus*, and about 20 species have been found to contain oil of commercial value. These oils, in turn, are

FIG. 10. Harvesting Eucalyptus leaves in Australia. (*Courtesy Fritzsche Brothers, Inc.*)

classified into three types, namely, medicinal, perfumery and technical oils.

Medicinal. These oils are distilled from several species of eucalyptus, for example, *E. polybractea*, *E. sideroxylon*, *E. leucoxylon*, *E. australiana* and *E. dives* var. "C". These trees are widely scattered through Australia. The foliage is removed from the trees and is distilled in numerous field stills. The yield of oil runs about three to four percent. The chief constituent is cineole and the oil has marked antiseptic properties. It is used in cough medicines, inhalants, rubbing oils and other medical preparations. The annual production of all eucalyptus oils in Australia amounts to about 240,000 gallons. Some medicinal eucalyptus oil is also produced in Spain and Brazil from *E. globulus*, and in the Belgian Congo it is obtained from *E. smithii*.

Perfumery. The main constituent in this oil is citronellal, along with geraniol and geranyl acetate. These oils have a sweet fragrance and are used for scenting soaps and cosmetics. The foliage from *E. citriodora* is the principal species used for producing the oil, which contains about 75 percent citronellal. Small quantities are also produced in Brazil. The foliage of *E. macarthuri* also serves as a perfumery oil. It contains about 60 percent geranyl acetate, ten percent geraniol, together with small amounts of butyric esters.

Industrial Oils. These are derived from the foliage of *E. dives*, *E. numerosa* and *E. australiana* var. "B" (*E. phillandra*). The oils contain piperitone and phellandrene as principle constituents. They are used in mineral flotation, manufacture of synthetic menthol and thymol, germicides and deodorants.

Camphor (26)

Camphor and camphor oil are present in all parts of the camphor tree (*Cinnamomum camphora*) which grows in China, Formosa, Japan, Java, Sumatra and Brazil. It is not known just when camphor was first used, but it appears to have been obtained by the Chinese in the latter part of the sixteenth century. The early camphor industry was aimed solely at recovery of crystalline camphor, no attention being paid to the production of camphor oil. Therefore no condensers were used in the distillation, and extraction was actually a process of sublimation. The vapors were conducted into porcelain bowls, and the camphor was condensed by air cooling.

It was not until the early part of the nineteenth century that water-cooled condensers were devised in the province of Tosa (Shikohan Island); from then on the camphor industry made remarkable progress. The new process of distillation yielded not only camphor but also an approximately equal amount of camphor oil which has lately reached almost greater importance than camphor itself.

In 1879 new progress was made in Japan's camphor industry with the discovery that the residual camphor oil still contained substantial quantities of camphor which can be recovered by fractionation.

The entire camphor tree, including branches, trunk, stump and roots, is comminuted for camphor production. On the average, the whole tree yields 1.5 percent of camphor and 0.7 percent decamphorized oil. Before World War II the total camphor products produced in Japan and Formosa amounted to 9,000 metric tons annually. With the production of synthetic camphor from α-pinene on a large scale, the natural product has lost some of its former importance. However, camphor oil has managed to retain its position because it contains, aside from camphor, a number of other components which are used in different industries.

Camphor is utilized as a plasticizer for cellulose esters and ethers; in the manufacture of plastics, particularly celluloid; in lacquers and varnishes; in explosives; as a moth repellent; and in the manufacture of cymene. In the field of medicine, it serves as a local analgesic and antipruritic, and as a circulatory and respiratory stimulant.

Sandalwood (25)

One type of sandalwood oil is obtained from the heartwood of *Santalum album*, a medium-sized tree growing in the southern parts of India and on the island of Timor. This oil is known as East Indian type; about 300,000 pounds are produced annually. It contains largely α- and β-santalol and is used mainly in perfumes, cosmetics and soaps.

Another sandalwood oil is obtained from the trunk and large branches of *Amyres balsamifera*, a tree growing on the island of Haiti. The yield of oil varies from two to four percent, and annual production is about 15 metric tons. It is a mixture of cadinol, cadinene and β-caryophyllene, and is employed as an adjunct in the scenting of soaps and various technical preparations.

Many other trees serve as sources of volatile oils, and the brief discussion above merely points out some of the better known oils of commerce.

TREE EXUDATES

The extractive components of trees which may be classified as tree exudates usually are not produced freely unless there has been injury of some kind. These wounds may be caused by other falling trees or branches in the forest or by animal or insect injury. Again, abnormal growth within the tree, such as separation of wood structure leaving cavities, may induce exudation. Thus, when the cambium or sapwood of certain trees is so wounded, apparently the tree is able to set up a defensive mechanism to heal the injury by producing or synthesizing certain chemical components. For this reason, for commercial purposes tapping of some form usually has to be resorted to in order to obtain free production of tree exudates.

As there are many varieties of trees, so it is that when injured or tapped, they produce different types of tree exudate. Since there appears to be some confusion as to the proper terminology to be applied to these various exudates, each type of exudate will be treated separately because each has quite different physical and chemical properties. Likewise their respective uses are quite different and interest different classes of users. In the limited discussion permitted here, only brief mention can be made of several types which are of commercial value.

Natural Resins (29)

Although natural resins are widely distributed in the plant kingdom, they are usually produced in small quantities

only, and economic importance is attached to comparatively few of them. Some of these exudates are obtained from living trees, such as damar. Other resins are of fossilized products of trees, for instance, Congo and kauri.

Natural resins are insoluble in water and are not to be confused with the water-soluble tree exudates, properly referred to as "gums". They are soluble to a greater or less extent in various organic solvents that have no effect on gums. Hardness is one of the most noticeable as well as one of the important properties of resins. In the natural state, resins may be extremely hard and brittle, such as amber and some of the copals. On the other hand, they may be so soft as to be easily kneaded with the fingers, as are the elemis. The color of resins is most variable and may range from colorless through various shades of amber and brown to pink. Most are transparent and break with a clear vitreous fracture, but some are opaque. Natural resins do not usually have a definite melting point, since they are complex mixtures instead of pure substances. On heating, fusion takes place gradually.

Most of the natural hard resins contain almost no volatile oil, which serves to distinguish them from oleoresins. Most resins consist essentially of acids and neutral bodies, termed "resenes". The resenes are inert substances notable for their resistance to chemical reagents and appear to be of an aromatic nature, but cannot be placed in any definite chemical category. Other important constituents of resins are aromatic acids and resinols, the latter of which are high molecular weight alcohols.

Copals are among the best of natural

FIG. 11. Transport of sandalwood to a Government factory in Mysore, India. (*Courtesy Fritzsche Brothers, Inc.*)

resins used in varnish and paint manufacture. They are derived mainly from trees of the family Leguminosae in various parts of the world. Some of the resins occur in the fossilized or semi-fossilized condition and have to be recovered from the ground.

Congo copal resin is considered to be derived mainly from *Copaifera demeusei*, a common tree of the Belgian Congo. The native collectors locate the pieces of resin by prodding the ground with iron tipped sticks. After collection, the pieces of resin are cleaned and graded for color and size by hand. The four main or basic grades are clear white, pale yellow, amber and brown. About 18,000 tons of the resin were produced in 1935, and the industry is still a valuable one. In addition to its use in varnish, because of its thermoplastic character, it has been used to produce pressed and stamped articles, often in combination with shellac.

West African copal is a fossil resin derived from *Copaifera copallifera*, which is also the source of a fresh resin obtained by tapping. This tree occurs from French Guinea to Nigeria. Trees are tapped by cutting squares of bark from the trunk at intervals, working upwards from the base. As the resin exudes, it forms nodules two to three inches in diameter which are allowed to dry and harden during the dry season before being removed.

East African copals have been held in high esteem by the varnish maker, being the hardest of all copals. This resin is derived from the tree *Trachylobium verrucosum* and may be collected from the living tree, from the soil in a semi-fossilized form, or fossilized from areas where the trees no longer exist. It is a tall evergreen tree in the coastal forest of Tanganyika and also in Kenya. A characteristic of this resin is its peculiar roughened surface which serves to distinguish it from all other copals.

East Indian and Manila copals, also known as "Manila resins", are obtained by tapping *Agathis alba* trees growing in Sumatra and the Philippines (39). Pieces of bark are removed and the exposed wood cleaned to provide a surface for the resin to exude and harden. After every resin collection, a thin slice of bark is removed from the upper edge of the wound to provide new openings in the resin ducts to stimulate flow. Average production is 26 pounds a year per tree. The major application of Manila is in oil and spirit varnishes and paints. They are also used in plastics, driers, linoleum, oilcloth and adhesives.

Another copal is obtained from *Agathis australis*, a very large coniferous tree native in Australia and New Zealand, the Kauri pine. Like many other copals, that from the Kauri pine is found in lumps buried in the ground. Most of these lumps are one or two inches in diameter, but some are much larger, weighing up to 100 pounds. Nearly all of this resin comes from the northern part of North Island of New Zealand. It is frequently called Kauri gum, though it is not a gum, but a true copal resin.

Dammar natural resins are derived from trees belonging to the family Dipterocarpaceae and are of great importance in the Indo-Malayan and East Indian regions. As a group, the dammars are characterized by their free solubility in turpentine and coal tar hydrocarbons which serves to distinguish them from the copals. They are of special value in the manufacture of so-called "spirit varnishes", owing to their pale color and good solubility.

The botanical sources of East Indies dammars are *Hopea dryobalanoides* and *Hopea globosa* in Java and eastern Sumatra. Malaya and Siam resins are obtained from *Balanocarpis heimii* which is one of the chief timber trees in Malaya. The collectors make a number of

FIG. 12 (*Upper*). Charging a still in Japan with chipped camphor wood for production of camphor and camphor oil. (*Courtesy Fritzsche Brothers, Inc.*)

FIG. 13 (*Lower*). A stationary field distillation post for production of eucalyptus oil in Australia. Placing a layer of mud paste on top of the still wall to tighten the still head to the vat. (*Courtesy Fritzsche Brothers, Inc.*)

incisions at intervals up the trunk and the resulting fluid resin gradually hardens.

Oleoresins

Oleoresins are tree exudates which are viscous liquids, insoluble in water but soluble in most organic solvents. They are distinguishable from natural resins in that oleoresins contain a steam-volatile oil fraction, usually terpene in nature, in addition to a non-volatile portion. The best known oleoresin has already been discussed, namely, pine oleoresin obtained from turpentining southern pines.

Another oleoresin is obtained from balsam fir (*Abies balsamea*), a coniferous tree indigenous to Canada and the northeastern United States (41). It is known as "Canada balsam" and "Canada turpentine". The term "balsam" is incorrectly applied to this oleoresin, since the true balsams are characterized by the presence of benzoic and cinnamic acids, both of which are absent from Canada balsam. It is also known as "Canada turpentine", and this, too, is actually incorrect, since it would imply that the oleoresin is entirely steam-volatile. This is not the case, since it contains 70–80 percent resin, together with 16–20 percent volatile oil. The volatile oil contains L-α-pinene, L-β-pinene, L-β-phellandrene and bornyl acetate (36).

The oleoresin is found under bark blisters and is secreted normally in canals formed by separation of the cells in the bark of the tree. It accumulates in small reservoirs forming blisters, and is often collected by puncturing the blisters with the pointed spout of a can into which the oleoresin then flows. It is a transparent and viscous liquid with an agreeable terebinthinate odor. A feature of this oleoresin is the little tendency it shows to granulate or crystallize on drying. This, together with its high refractive index, accounts for its use in microscopic work and as a cement for lenses in optical work. It is also used for making spirit varnishes and as an antiseptic dressing for cuts and wounds.

The oleoresin from Douglas-fir (*Pseudotsuga taxifolia*), also known as "Oregon balsam" or "Douglas-fir turpentine", both terms being inappropriate for reasons already discussed, is found in cavities or pockets produced in the trees by windshake (48). These cavities, in time, fill with oleoresin, and when an opening is cut into such a region, the oleoresin flows out. It is a transparent, syrupy liquid, with a pleasant aromatic odor. It has a pale, greenish-yellow color and consists of a volatile oil (26–38 percent) containing α- and β-pinene. It is used in the manufacture of varnish and porous plasters and in the ceramics industry.

Elemi is an oleoresin obtained from *Canarium luzonicum*, a large Philippine tree, by making gashes in the trunk (30). It contains 20–30 percent volatile oil. When fresh and of good quality, elemi is pale yellow, soft and granular, but on ageing and losing its volatile oil it darkens and sets. It is employed in varnish, printer's ink, and in ointment.

Gums (31)

True gums are polysaccharides, which are either soluble or colloidally soluble in water. Being polysaccharides they are insoluble in organic solvents, which distinguishes them from resins and oleoresins soluble in organic solvents. Gums, on heating, decompose completely without melting, while resins and oleoresins melt. Gums are totally unrelated to resins—physically, chemically and in application.

True gums may be divided into two main groups: *a*) soluble gums, such as gum arabic, which dissolve in water, forming transparent, viscous and adhesive solutions; and *b*) insoluble gums,

such as gum karaya, which when placed in water absorb it and swell into a thick jelly, which, with additional amounts of water, forms a thick translucent solution.

The color of solid gum varies almost from water white, through various shades of yellow, amber and dark brown. Some of the best grades of gum arabic are almost colorless. They are usually odorless and some may be tasteless, some slightly sweet or even bitter, according to botanical origin. Most gums break with a clear glossy fracture when properly dried. They are generally hygroscopic and will absorb moisture and become soft in humid atmosphere. Viscosity of a solution that a gum forms with water is of paramount importance in determining the quality or value of a gum—the higher the viscosity the better the gum. The viscous solutions of gums in water are colloidal in nature. They exhibit swelling pressures and form gels at very low concentration. In effect, they prevent agglomeration and settling of finely divided particles and precipitates. It is this property that renders gums valuable in many of their uses, notably in the textile, cosmetic, pharmaceutical and food industries.

As previously mentioned, true gums are polysaccharides which, when subjected to acid hydrolyses, are broken down to their components, namely, simple carbohydrates, for instance, arabinose and galactose, and a carbohydric acid, such as aldobionic, galacturonic or glucuronic acids. Sometimes the gums contain mineral matter—calcium, magnesium, or potassium—usually in the form of a salt.

One of the main uses of gums by man is still as food, for the bulk of imported gum enters the confectionary trades. Gum arabic is used in medicines, principally as a vehicle in a large number of proprietary preparations. Other uses include treating textiles and paper, in calico printing and dyeing processes.

While there is a considerable variety of trees producing gums, only two will be considered here, for they are of greatest commercial interest.

One of the most productive gum arabic areas is the Anglo-Egyptian Sudan region. Over 21,000 long tons of the product were exported annually before World War II. Although there are many species of *Acacia* in the Sudan, commercial gum is obtained almost entirely from one species—*Acacia senegal*. The tree is from 15 to 20 feet in height and often branched from near the ground.

A small axe is used in tapping. The blade is driven lightly under the bark, and then the two severed ends pulled, one up and one down, causing long strips of bark, one to two inches wide, to be torn from the tree. The gum forms as "tears" in various places along the stripped section, where they are allowed to dry, then collected. Some of the gum is graded by hand picking. Sun bleaching is carried out by carefully spreading the tears on sheets in the sun for several weeks. This gives a more uniform color.

In addition to Sudan, acacia gums are obtained from French West Africa, Nigeria, East Africa, North Africa, India and Australia.

Karaya gum, or "Indian tragacanth" as it is also called, is obtained from *Sterculia urens*, a widespread tree in India (40). It is a large deciduous tree with a characteristically smooth white or green grey bark which peels off in large, thin, papery flakes. Gum is produced freely by the tree when tapped. The method of tapping or blazing the trees has an important bearing on their health and their life. The blaze, not larger than a square foot, should be cut so as to allow water to drain freely, for water-retaining pockets are liable to cause rot. After the first collection of gum has been made, the edges of the blaze are scraped to encourage further production of gum.

The gum is collected and graded. Gum karaya is a galactan. In 1939 imports to the United States were over 7,600,000 pounds. It is used in the textile, food, cosmetics and other industries.

It may be pointed out here that, while most true gums are obtained as exudate, as just described, the wood of some tree species has been extracted with hot water for the production of water-soluble polysaccharides of the gum type. For example, western larch (*Larix occidentalis*) contains eight to 18 percent of an arabo-galactan, the larger amounts being found in the heartwood of the old-growth butt logs. It is also present in eastern larch (*Larix laricina*). While some 30 years ago western larch was extracted for production of gum which in turn was oxidized to mucic acid, the operation lasted but a short time.

Balsams (32)

True balsams are resinous exudates whose fragrant aroma and pungent taste are due to the presence of benzoic or cinnamic acid, or both. The best known of these are storax, balsam of Peru and balsam of Tolu.

Storax is a balsam obtained from *Liquidambar orientalis*, a medium-sized forest tree in Asiatic Turkey. To obtain the balsam the usual method is to beat the bark in places in early summer. The balsam collects in the spongy bruised bark which is removed in the autumn, and the balsam is extracted by boiling in water and pressing. Crude storax is a viscid semi-fluid substance, greyish in color, with a pleasant aromatic odor. The purified product is semi-transparent and yellowish-brown. It contains 33–50 percent storesin and various esters of cinnamic acid, 5–15 percent free cinnamic acid (42). It is used for perfuming soaps and talcum powder, in flavoring tobacco and also for medicinal purposes.

Peru balsam is obtained from *Myroxylon pereirae*. The tree grows in southern Mexico and extends southward through Central America, mainly on the Pacific side. It grows as high as 100 feet with a trunk up to three feet in diameter. The usual Indian method of obtaining the balsam is somewhat crude and liable to injure or kill the tree. The trunk is first beaten in several places over a surface of about half a square foot to loosen the bark, and the outer portion of the bark removed. The exposed surfaces are then covered with a piece of cloth to absorb the exudation. At intervals the surfaces are scorched with a torch and then the inner bark removed to stimulate flow. Eventually the cloth is boiled and pressed to separate the balsam. The tree does not normally exude the balsam to any extent, hence the special treatment.

Peru balsam contains 50–60 percent cinnamein—esters of cinnamic and benzoic acid, about 28 percent styracin, and vanillin (43). In Salvador the best trees yield between four and five pounds of balsam a year. It is used medically as an antiseptic and parasiticide; also in perfumery and soap making. The annual production of Peru balsam in Salvador is about 150,000 pounds, of which nearly half is exported to the United States.

The tree yielding Tolu balsam, *Myroxylon balsamum*, is widely distributed in South America, being common in parts of Brazil and the Argentine, where it is used as timber. Most of the Tolu balsam that enters commerce is obtained from Colombia and Venezuela. The trees are tapped by cutting V-shaped gashes in the bark and using calabashes to collect the resin, which is transferred to skin bags for transport to the coast and finally put into tins for export. When fresh the balsam is a soft, tenacious, yellowish-brown mass, but in time it hardens and eventually becomes brittle. It contains 12–15 percent free cinnamic and benzoic acids as well as about 40 percent esters of these acids,

and a small amount of volatile oil. It is used in medicinal preparations, mainly as a pleasant ingredient in cough mixtures, and in the perfumery industry.

Latex

Rubber is a product obtained from latex, a milky secretion which is found in the tissue of a large number of plants. When the plant is injured, latex flows from the wound, and on exposure to air it coagulates and darkens. Rubber is mainly a hydrocarbon.

Of the many plants yielding latex in quantity, the Para rubber tree (*Hevea brasiliensis*) stands in first place (55). It is a member of the Spurge Family, and is found in the Amazon jungle. Most commercial rubber is obtained from plantations of *Hevea*, grown in what is now Indonesia. In tapping, a spiral cut is made in the bark, care being taken not to injure the cambium. A spout is placed at the lower end of the cut, and the exuding latex collected in porcelain cups. Periodically a thin shaving is removed to cause additional latex flow. Shaving continues over a period of three to eight weeks, after which the tree is left undisturbed to recover.

The latex is gathered from the cups and coagulated by different methods. In one of these, acetic acid is added to the fresh latex, which has been set in shallow pans. The rubber then forms as a sheet on the surface of the liquid. The sheets are removed and squeezed between rollers to remove excess moisture. The resulting product is crêpe rubber. Some latex is treated with ammonia and shipped in liquid form to the rubber factories. This in turn can be treated to form the many well known products of the rubber industry.

Maple Sugar (49)

The only industrially important tree from which sugar is obtained from the sap is the maple. The chief sources are the sugar maple (*Acer saccharum*) and the black maple (*Acer nigrum*), deciduous hardwood trees of eastern North America. To obtain the sap, small holes are bored into the sapwood near the base of the trunk, a channeled spout driven into each hole, and a bucket hung on the spout. The ready flow of sap occurs in the early spring when tree metabolism and growth are again becoming active, usually between the middle of March and the first part of May. The usual yield is ten to 15 gallons of sap per tree, which is equivalent to about three pounds of sugar. The colorless syrup is poured into pans and evaporated with wood fires, producing a thin brownish syrup. The syrup may be further concentrated until it crystallizes as a brown sugar. Maple products are used to flavor tobacco and in candy manufacture. The principal producing regions are Vermont, New York and other New England States. The annual production in the United States in 1944 was 21 million pounds.

Maple tree sap contains about three percent sucrose with small amounts of invert sugar. Also present are organic acids, chief of which is malcic, largely in the form of potassium and calcium salts.

MISCELLANEOUS

A number of waxes in commercial use are derived from palm trees. The best known and by far the most important is carnaúba wax obtained from the leaves of the palm tree *Copernicia cerifera* (58). The natural habitat of this tree is Brazil.

Carnaúba is a straight-trunked palm of slow growth, attaining an average height of only 25–40 feet, even after 50 years of growth (58). The bark is scaly, rough and thick, and the leaves grow out from yard-long petioles in wide serried fan shapes. While this tree is perhaps best known as the source of carnaúba wax, to the Brazilian setão it is literally the tree of life. This palm supplies him

not only food, drink and a cash crop, but also fibers for clothing, timber for householding and also his light. The trunk is used for piling, since it is very resistant to insect attack, bark for firewood, the leaves for window and door shades, the tender end-shoots are a food and can also be made into wine, vinegar and a saccharine substance. The fruit may be crushed for cooking oil, and when the fruit is roasted it may be brewed to a coffee-like drink. A flour can be prepared from the medullary pith, or the pith may be fermented to an alcoholic drink. A medicinal substance is extracted from the roots. The saplings are sometimes fed to cattle as fodder. The leaves are woven into hats. Cordage, nets, baskets, mats and curtains are also woven from the fibers. Thus it is apparent that the life of these Brazilians centers around the palm tree —which certainly is one of the best illustrations of thoroughly integrated and diversified utilization of a natural product.

Cutting and harvesting of the leaves generally take place during the dry months of the year, usually between September and January. The collectors chop through the stem with a curved sickle-like knife fastened to the end of a long pole. As the leaves fall to the ground, the long stems are slashed off and then the leaves are carefully transported to a central terrace for drying in the sun. There are two cuttings (60 days apart) per tree in a normal year, but there is a yield of only eight to 12 leaves per cutting.

After the leaves have dried for several days, they are carefully taken to a threshing shed and ripped apart by hand to loosen the wax. They are then beaten against a wooden sawhorse to remove all the wax dust. The dust is swept into small bins or bags preparatory to melting.

Melting is carried out in shelters in either clay vessels or iron pots, directly over a wood or charcoal fire. The wax is also often bagged in powder form and shipped to the coast. The melted wax is stirred during the heating and then strained through a thick cloth. The wax is allowed to cool, and the hardened material hammered into chunks.

On the average, a leaf will yield about five grams of wax. Various modifications in the recovery and melting procedure are necessary to obtain the classified grades of carnaúba wax, as they are known commercially. The total import of carnaúba wax into the United States in 1950 was 9,600 short tons.

Carnaúba wax essentially consists of myricyl cerotate and small quantities of cerotic acid and myricyl alcohol.

This wax is largely used in the floor polishing industry, auto polish and leather dressing. It plays an important part in the manufacture of carbon papers and in candle manufacture. Other uses are in photographic film, chalk, matches, soap and woodwork stains.

Tung oil, known also as "China wood oil", is expressed from the seeds of the tung oil tree (*Aleurites fordii*), a native of China and Japan (50). Increasing importance of tung oil in the paint and varnish industries led to extensive experimental planting of tung trees in the United States. The greatest acreage is in Mississippi, followed closely by Florida. Production of native tung oil reached five million pounds in 1942.

Tung oil is a fixed oil, which is nonvolatile. It is a fatty acid glyceride and is classed as a drying oil, for, on exposure to air, it forms a tough elastic film. The oil is expressed from the seed contained in the fruit. The fruit matures in September or October and is allowed to fall to the ground. In the United States the oil is expressed in modern mills, using a decorticator and an expeller press. The seeds yield about 20

percent oil. The oil is used principally in the manufacture of waterproof or spar varnishes, enamels and other paints; also in linoleum, oilcloth, inks and soap.

Quinine is the most important alkaloid of the bark from the cinchona tree (*Cinchona ledgeriana*) (5). This tree, which is native to the Andean region of the American Tropics, was transplanted to the Far East by the English and the Dutch in the middle of the Nineteenth Century. There it flourished in well tended plantations, and before World War II the Netherland Indies (now Indonesia) alone accounted for 84 percent of the total world production of cinchona bark. Bolivia was the most important Latin American supplier. Cultivated plantings are increasing, and output, particularly from Guatemala, is expanding.

Quinine sulfate, a specific for malaria, is the principal product of the bark, although it also yields small quantities of quinident, used in certain heart ailments; cinchonine; cinchonidine; and other medical alkaloids. The trees require several years to mature sufficiently so that the bark can be harvested. About ten years are required between planting of seedlings and peak harvesting.

The bark gatherers fell the tree, strip off the bark, dry it and pack it for marketing. United States prewar imports of bark averaged 1,777,000 lbs. in 1935-39, and imports of alkaloids (in terms of bark) averaged slightly less than that quantity. All came, either directly or indirectly, from the Netherland Indies. During the war, however, when supplies from the Far East were unavailable, Latin America furnished limited quantities. In 1946 Guatemala sent three-fourths of the total import. By 1947 Netherland Indies production was again on the market. With the perfection of atabrine and other synthetic medicinals, chemists have forged a new tool for the treatment of malaria by the combined use of quinine and synthetics.

SOME NEWER DEVELOPMENTS

There are some interesting developments being carried out in the chemistry of barks at the Oregon Forest Products Laboratory. Kurth and his colleagues have recently found, among other things, that Douglas-fir bark (*Pseudotsuga taxifolia*) contains, in addition to the previously known tannin, an abundance of wax and also dihydroquercitin (37). The yield of wax is five to ten percent; tannin, eight to 18 percent; and dihydroquercitin, around seven percent. A preliminary market research study has revealed that each of the products appears to have good commercial outlets. An integrated extraction process has been developed and a pilot plant is soon to go into operation.

Several years ago the Western Pine Association Research Laboratory discovered that old ponderosa pine stumpwood (*Pinus ponderosa*), a logging residue, contains up to 25 percent rosin together with small amounts of volatile oils (1). A small extraction plant has been installed to determine the potential commercial value of this newly discovered source of rosin. Further, the Oregon Lumber Company Research Laboratory recently developed a process which employs ponderosa pine stumpwood or any other resinous wood as a binder and sizing agent in fiberboard production (3). By employing this logging waste, which is rich in resinous extractives, in fiberboard compositions, it replaces the more costly synthetic binders and sizing agents.

More recently the University of California Forest Products Laboratory has found that sugar pine heartwood (*Pinus lambertiana*) mill waste and stumpwood contain relatively large amounts of pinitol, a cyclitol (4). The mill waste yielded about four percent, while stump-

wood gave eight percent yields of this interesting product. The cyclitol is readily recovered from the comminuted wood by water extraction. Market research studies are planned to ascertain the potential commercial value of this extractive product.

Conidendrin, a lignan, has been recovered from sulfite waste liquor on pilot plant scale (38). It has been suggested that derivatives of conidendrin be used as antioxidants and for pharmacological purposes.

Research is being conducted in England on the nature of extractives in tropical hardwoods of British Guiana to find additional outlets other than physical utilization (18). The heartwood of one of these hardwoods, namely, wallaba (*Esperua* sp.), is very resinous, containing up to 30 percent extract, soluble in acetone or alcohol. The resin is not of the abietic acid type but of a phenolic nature. Catechol is readily obtained from it on destructive distillation. And the non-aqueous part of the liquid distillate is reported to be highly toxic to wood-destroying fungi and may therefore be useful as a wood preservative. The heartwoods of mora (*Mora excelsa*) and morabukea (*Mora gonggrypii*) are likewise relatively rich in extractives which are recovered by hot water or alcohol. The principal extractive in each case is a saponin, yields being from three to ten percent. However, present appraisal would indicate that the production of extract from these woods is unlikely to be feasible commercially unless a profitable outlet can be found for the fibrous residue remaining after extraction.

SUMMARY

There are many valuable or potentially valuable chemicals that can be obtained from various tree species but which are not yet being recovered or utilized. This stems from the fact that processing the trees for extract recovery alone will, in most instances, not pay its way. However, if integrated utilization methods are considered along with recovery of extractive, such processing may become profitable. Examples of such integrated processing now in operation are the use of exhausted chestnut wood chips after tannin extraction for pulp and the utilization of spent southern pine stumpwood chips for manufacturing fiberboard sheathing. Thus the entire field of potentially commercially available extractives from trees should be reappraised with integrated processing in mind. Processing a raw material for single product recovery, at best, is a hazardous undertaking, while diversified processing of a raw material to produce multiple useful products through integrated processing lends stability to that industry. One need not look far to find that the most stable and expanding of our industries are based on diversified product manufacturing.

LITERATURE CITED

1. Anderson, A. B. Rosin and other extractives from ponderosa pine stumps. Paper Trade Jour. 129(2): 35–37. 1949.
2. ——— and Gripenberg, J. Antibiotic substances from the heart wood of *Thuja plicata* D. Don. IV. The constitution of β-thujaplicin. Acta Chem. Scand. 2: 644–650. 1948.
3. ——— and Runckel, W. J. Utilization of resinous wood in hardboard. Jour. For. Prod. Res. Soc. 2(5): 76–80. 1952.
4. ———. Pinitol from sugar pine stump wood. Ind. & Eng. Chem. 45(3): 593–596. 1953.
5. Anonymous. Cinchona in Guatemala. U. S. Dept. Agr., For. Agr. April 1948.
6. ———. [U. S. For. Serv., Bur. Ent. & Plant Quar., and Bur. Plant Ind.]. A naval stores handbook. U. S. Dept. Agr., Misc. Publ. 209. 1935. p. 36–59, 147–166.
7. ———. Review and outlook, naval stores. U. S. Dept. Agr., Bur. Agr. Econ. 1951. [p. 10].
8. ———. *Ibid.* [p. 21–24].
9. Benson, H. K. Chemical utilization of wood. U. S. Dept. Comm., 22nd Rep.

Nat. Comm. Wood Util. 151 pp. 1932. [p. 103–106].
10. Buchanan, M. A. The tannins and coloring matters. *In:* Wise, L. E., and E. C. Jahn, Wood chemistry. Vol. 1. Chap. 15. 1952. [p. 624].
11. ———. *Ibid.* [p. 622–626].
12. ———. *Ibid.* [p. 628–636].
13. Dorman, K. W., and Clements, R. W. Results of commercial scale chemical stimulation tests. Part I. Naval Stores Rev. **56**(38): 12–14, 16. 1946.
14. ——— and ———. Results of commercial scale chemical stimulation. Part II. Naval Stores Rev. **56**(40): 7–8. 1947.
15. Erdtman, H., and Gripenberg, J. Antibiotic substances from the heart wood of *Thuja plicata* D. Don. II. The constitution of γ-thujaplicin. Acta Chem. Scand. **2**: 625–638. 1948.
16. ———. Die phenolischen Inhaltsstoffe des Kiefernkernholzes, ihre physiologische Bedeutung und hemmende Einwirkung auf die normale Aufschliessbarkeit des Kiefernholzes nach dem Sulfitverfahren. Ann. Chemie **539**: 116–127. 1939.
17. ———. Organic chemical research in the Department of Organic Chemistry, Royal Institute of Technology, Stockholm, during the years 1945–1950. Svensk. Kem. Tidsk. **63**: 48–51. 1951.
18. Farmer, R. H., and Campbell, W. G. Chemical utilization of tropical hardwoods. TAPPI **35**(4) (Tech. Sect.): 181–183. 1952.
19. Flinn, E. S. Wood tannins. *In:* Nature of the chemical components in wood. TAPPI Mono. Ser. **6**. Chap. 7. 1948. [p. 147].
20. ———. *Ibid.* [p. 146].
21. Freeman, Mary F. Continuous flash type still may revolutionize the industry. Naval Stores Rev. **56**(52): 16–17. 1947.
22. Freudenberg, K. Die Chemie der Naturalichen Gerbstoffe. 1920.
23. Gripenberg, J. Antibiotic substances from the heart wood of *Thuja plicata* D. Don. III. The constitution of α-thujaplicin. Acta Chem. Scand. **2**: 639–643. 1948.
24. Guenther, E. Recent developments in essential oil production. Econ. Bot. **6**(4): 355–378. 1952. [p. 362–364].
25. ———. *Ibid.* [p. 372–373].
26. ———. The essential oils. Vol. 4: 257–328. 1950.
27. Harris, G. C. Wood resins. *In:* Wise, L. E., and Jahn, E. C., Wood chemistry. Vol. 1: 607. 1952.
28. Hepting, G. H. Stimulation of oleoresin flow in pines by a fungus. Science **105**: 209. 1947.
29. Howes, F. N. Vegetable gums and resins. 1949. [p. 85–89, 115–148].
30. ———. *Ibid.* [p. 141].
31. ———. *Ibid.* [p. 3–44].
32. ———. *Ibid.* [p. 162–165].
33. Humphrey, I. W. Solvent refining of wood rosin. Ind. & Eng. Chem. **35**: 1062–1067. 1943.
34. Kurth, E. F. The volatile oils. *In:* Wise, L. E., and Jahn, E. C., Wood chemistry. Vol. 1: 574. 1952.
35. ———. *Ibid.* [p. 579].
36. ———. *Ibid.* [p. 568].
37. ———. The Timberman: 116–117. March, 1952.
38. Lackey, H. B., Moyer, W. W., and Hearon, W. M. A new method of isolating conidendrin from sulphite waste liquor. TAPPI **32**(10): 469–471. 1949.
39. Mantell, C. L. The natural hard resins—Their botany, sources and utilization. Econ. Bot. **4**(3): 203–242. 1950. [p. 237–241].
40. ———. The water-soluble gums—Their botany, sources and utilization. Econ. Bot. **3**(1): 3–31. 1949. [p. 17–18].
41. Marriott, F. G., and Greaves, C. The chemical utilization of wood. Dept. Int., Ottawa, Canada. 1935. [p. 266–267].
42. Merck Index, 6th ed. 1952. [p. 906].
43. ———. *Ibid.* [p. 114].
44. Mirov, N. T. The terpenes (in relation to the biology of the genus *Pinus*). Ann. Rev. Biochem. **17**: 521–540. 1948.
45. Palmer, R. C. Turpentine and rosin from wood wastes by the steam and solvent process. Ind. & Eng. Chem. **26**: 703–706. 1934.
46. Panshin, A. J., Harrar, E. S., Baker, W. J., and Proctor, P. B. Forest products. 1950. [p. 469–477].
47. ———, ———, ———, and ———. *Ibid.* [p. 479–481].
48. ———, ———, ———, and ———. *Ibid.* [p. 511–513].
49. ———, ———, ———, and ———. *Ibid.* [p. 454–467].
50. ———, ———, ———, and ———. *Ibid.* [p. 505–508].
51. Pew, J. C. A flavone from Douglas-fir heartwood. Jour. Am. Chem. Soc. **70**: 3031–3034. 1948.
52. Pomeroy, K. B. Modern trends in an ancient industry. Jour. For. **50**(4): 297–299. 1952.
53. Shearon, W. H. Chemical industry in western South America. I. Paraguay,

Uruguay, Chile, Bolivia. Chem. & Eng. News 31(37): 3736–3741. 1953.
54. Stamm, A. J., and Harris, E. F. Chemical processing of wood. 1953. [p. 477–479].
55. ——— and ———. *Ibid.* [p. 435–437].
56. Wagner, H. B. World trends in supplies, distribution and prices of naval stores, 1934–49. U. S. Dept. Agr., Prod. & Market. Admin., July, 1950. 95 pp. [p. 7].
57. ———. *Ibid.* [p. 11–18].
58. Warth, A. H. The chemistry and technology of waxes. 1947. [p. 99–108].

Utilization Abstract

Flower Oil Industry of North Africa. There is some commercial production of jasmine oil in Egypt, near Cairo, and in Algeria, and in the latter country some oil of geranium and of neroli bigarade is also produced. Neroli is a by-product in the distillation of orange flower water and is used by natives in North Africa for flavoring confectionary and baked goods.

It is in Morocco, where land and labor are much lower priced, that an essential oil industry has been developing, based principally on the native Moroccan rose. This rose has ben identified by one authority with *Rosa centifolia* (the species cultivated in the Grasse region of southern France) and with *R. damascena* (the species cultivated in Persia and Turkey, and particularly in Bulgaria). "It is quite possible that the rose brought along by the Moors about 1200 years ago originally was *Rosa damascena*, or even a more primitive parent species. However, as a result of ecological and cultural factors, the plant may have gradually undergone some morphological changes, and finally developed into a variety similar to *Rosa centifolia*. Moreover, it is a well known fact that species of the genus *Rosa* hybridize readily—and this may have happened with the early Moroccan rose".

In southern Morocco gathering of rose blossoms has centered in the arid Dadès Valley, "a valley dotted with casbahs (a kind of medieval castle built of sun-baked mud) and inhabited by fierce Berbers. . . . It was only in the late thirties that Europeans could stay there for any length of time, without running the danger of being ambushed and massacred". Nevertheless, in recent years two French concerns have erected extraction plants in the area and have operated by solvent extraction or steam distillation from fresh blossoms.

"In the Dadès Valley roses are not cultivated as special plantings, but rather between trees in the form of dense hedges around small native fields of cereals and leguminous crops, in order to keep out grazing sheep and goats. The buds are collected in March and April, before they have opened up, and are then dried in the sun. Five kilograms of fresh buds yield about one kilogram of dried buds. The flowers are gathered in a rather careless way by the natives as a sort of family industry, little attention being paid to quality".

While the rose oil industry in southern Morocco depends entirely on flowers grown and gathered by the natives, in the northern part of the country an industry based on modern agricultural practices and extensive plantations of rose has been developed in the last ten years by large-scale French producers. Jasmine and other oils, in addition to that of rose, are concerned. (Ernest Guenther, *Am. Perf. & Ess. Oil Rev. 62(3): 185. 1953*).

Alkaloid Hunting

About 950 alkaloids have been isolated and named from the two percent of all species which have been tested for them. As a guide in further search for alkaloids, their presence in and absence from some 250 families of plants are here tabulated.

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Introduction

Alkaloids have been known for a long time. Henry (8) states that the first crystalline one, narcotine, was obtained by Derosne in 1803. From then on, events occurred rather rapidly. Henry goes on to say: "Between 1817 and 1840 practically all the more important alkaloids were isolated, including emetine, veratrine, strychnine, piperine, caffeine, quinine, berberine, coniine, atropine, codeine, thebaine, cinchonine, hyoscyamine, curarine, quinidine, aconitine and colchicine". By the end of 1952 about 950 had been isolated and named. These had been found in about 77 families, 317 genera and 807 species. In addition to these alkaloids which have been named and their chemical characters determined in greater and less detail, the presence of alkaloids has been established in still another 20 families, about 220 genera and 395 species. Thus at the end of 1952 alkaloids were known to be present in aproximately 97 families, 519 genera and 1202 species. Even so, only 2% of all species are on record as having been tested for alkaloids.

Interest in alkaloids still continues. Pharmacognosists are still exploring the occurrence of particular alkaloids in the botanical world; pharmacologists are evaluating the physiological action of new ones brought to light; chemists are solving their structures and producing derivatives; nations are exploring their native flora for useful alkaloid drugs; and plant physiologists are still pondering the question, why do plants make all these nitrogenous compounds?

The purposes of the present article are to show the present world-wide interest in alkaloid studies, to put on record the statistics in this field up to the present, and to indicate where in the botanical world there may be profitable hunting in the future.

Recent and Present Activity

Probably the most intensive and extensive surveys of plants for alkaloids is that under way in Australia and reported on by L. J. Webb. He states: "A systematic field survey of the Queensland flora for alkaloids was begun by this Council in September 1944 as a continuation of the war-time project which aimed to grow important foreign drug plants in Australia, and to locate and develop substitutes from local plants for drugs in short supply. . . . Queensland was chosen as the first site

for surveying, since it offers diverse vegetational types and large areas of tropical rain forest". Three publications on this work have been issued (26–28). In addition, intensive chemical work has been started on the alkaloids of Australian Rutaceae (12).

Recently Russian expeditions went into Central Asia and the Trans-Baikal region to look for alkaloid-bearing plants, and 60 or more new species were found (7, 13, 17).

Arthur (1) screened over 200 species of plants in North Borneo.

In the Argentine Codoni (6) looked for alkaloids in the bark of native trees, and Novelli and Orazi (18) collected published information on the drug plants of the country.

In our laboratory an extensive survey of plants is under way, primarily to search for steroidal sapogenins. Incidental to this, qualitative tests for alkaloids and other groups of constituents were applied to all plant samples. Although the results for the first 1000 samples only have been published (24, 25), we are including here the alkaloid data on the first 3000 samples. The list includes species indigenous to the Americas and to South Africa, and exotic species grown in botanical gardens in the United States.

Besides the above regional surveys, in some countries particular plant families are being studied assiduously, not only as to occurrence of alkaloids but also as to their identification, structure and physiological activity. Thus in Canada it is the Papaveraceae (Fumariaceae) and Leguminosae (Papilionaceae) (15, 23); in New Zealand, Leguminosae (30); in Spain, Papilionaceae (19); in Japan, Menispermaceae, Berberidaceae and Magnoliaceae (20–22); in Russia, Ranunculaceae and Leguminosae (11, 32). In other places the field of study is more limited—*Mahonia* in India (3), *Holarrhena* in Germany (2), *Erythrina* in the United States (10).

A perennial field of study and speculation is the degree to which alkaloids "run in families", or, more generally stated, the relation of chemical constituents to taxonomy. Claus (5), using the occurrence of alkaloids as one of his criteria, concluded that in the Liliaceae "The taxonomy of this family as based on phytoconstituents appears to substantiate, in most instances, the taxonomy based on morphological characteristics". When he came to the whole plant kingdom, however, he (4) concluded: "At present, the role of phytoconstituents seems to have no relation to phylogenetic taxonomy, although possibilities for its use in general taxonomy are definite. The field of phytochemical investigation has much to offer before a complete relationship between the constituents of plants and the taxonomic arrangement of plants can be conclusively established".

Webb (28) gives considerable thought to the relation between alkaloids and taxonomy as he found it in Queensland plants. A few quotations will illustrate his deductions: "Within a family such as Apocynaceae, certain tribes contain alkaloidal species, while in other tribes such species are absent. . . . . Within genera such as *Evodia*, *Acronychia*, or *Melicope* in Rutaceae, it will be observed that comparatively few species contain alkaloids".

"The reason is obscure for this erratic occurrence of alkaloids among plants regarded as closely related on conventional taxonomic grounds. It is, however, less puzzling when other constituents besides alkaloids are considered. Thus, some local non-alkaloidal Rutaceae nevertheless contain chromenes and flavones of similar basic structure to the alkaloids in related species (*Melicope*, *Medicosma*, and *Evodia*). Apparently these species do share certain metabolic pathways which later diverge, depending on their evolutionary histories. . . . Chemical data have already proved of value in

the classification of several Queensland plants. *Zanthoxylum brachyacanthum* F. Muell. and *Z. veneficum* Bail. are chemically indistinguishable, and it is now realized that probably only one species is represented. On the other hand, *Strychnos psilosperma* F. Muell. and *S. arborea* A. W. Hill are doubtfully distinct botanically, yet differences between their alkaloids suggest that they should be separated".

Henry (9) cites many interesting examples on both sides of the question. In some cases alkaloids and taxonomy fit hand in glove; in others they bear no mutual relation. Perhaps the safest conclusion at present is that not enough plants have been studied as yet to justify deductions.

Lists of Alkaloid Plants

A list was compiled of the families, genera and species known to contain alkaloids. This was done by searching Wehmer (29), Henry (9), Manske and Holmes (16), Biological Abstracts through 1949 and Chemical Abstracts through 1952 and partly through 1953. A few items were picked up in other places.

These sources gave only the known occurrences, since in general negative findings, in this case known non-occurrence, do not appear in the technical literature. Since it is useful for an alkaloid hunter to know where alkaloids have been sought and not found, this information was also collected. The sources were largely Webb (26–28) who gives all results of alkaloid testing on a large number of Australian plants, and the 3000 samples at this laboratory mentioned above. A few other published non-occurrences of alkaloids were acquired in various places.

Besides listing the number of species, per family or per genus, known to contain or not to contain alkaloids, we thought it would be of interest and value to give the size of the family or the genus.[1] This would indicate the degree to which the family or genus has been explored. The total compilations resulting from these searches are formidable—so much so, in fact, that all of them cannot be presented here. Two tables were prepared, one by families and one by genera. Table I, given here, lists the major families generally recognized by botanists, about 235, the approximate number of species in each, and the number of species on which there is alkaloid information, either for its presence or absence. The following 48 families, with 238 species, which are extremely small and on which there is no alkaloid information, are not given in Table I. The number after the family is the number of species in it:

Achariaceae, 3
Adoxaceae, 1
Ancistrocladaceae, 12
Batidaceae, 1
Brunelliaceae, 8
Butomaceae, 9
Caryocaraceae, 15
Crypteroniaceae, 4
Cephalotaceae, 1
Ceratophyllaceae, 3
Cneoraceae, 12
Columelliaceae, 3
Coriariaceae, 10
Corynocarpaceae, 3
Crossosomataceae, 3
Cynocrambaceae, 2
Cynomoriaceae, 1
Datiscaceae, 5
Diapensiaceae, 10
Empetraceae, 8
Eucryphiaceae, 5
Geissolomataceae, 1
Ginkgoaceae, 1
Gomortegaceae, 1
Gonystilaceae, 7
Grubbiaceae, 3
Hydnoraceae, 7
Hydrocaryaceae, 11
Krameriaceae, 13
Lactoridaceae, 1
Leitneriaceae, 1
Lennoaceae, 5
Limnanthaceae, 8
Mayacaceae, 7
Myrothamnaceae, 2
Oliniaceae, 6
Opiliaceae, 6
Pentaphylacaceae, 2
Phrymaceae, 1
Salvadoraceae, 8
Saururaceae, 4

[1] Because of differences in concepts among botanists and because new discoveries are still being made, neither the size of the family nor of the genus can be given with absolute finality. The figures are, in general, conservative.

TABLE I

MAJOR FAMILIES OF FLOWERING PLANTS, WITH THE TOTAL NUMBER OF SPECIES AND THE NUMBER OF SPECIES WITH KNOWN POSITIVE OR NEGATIVE TESTS FOR ALKALOIDS

Species	Total	Alkaloids Pos.	Alkaloids Neg.
Acanthaceae	2,400 +	3	6
Aceraceae	150	...	6
Actinidiaceae	285	...	1
Aizoaceae	600	5	4
Alismataceae	60	...	1
Amaranthaceae	800	2	14
Amaryllidaceae (1)	1,310	45	112
Anacardiaceae	600	1	15
Annonaceae	850	8	15
Apocynaceae	1,300	59	61
Aponogetonaceae	22	...	...
Aquifoliaceae	300	1	7
Araceae	1,500	...	13
Araliaceae	800	...	12
Aristolochiaceae	400	10	3
Asclepiadaceae	1,800	12	27
Balanophoraceae	40	...	1
Balanopsidaceae	10	...	1
Balsaminaceae	450	...	1
Basellaceae	22	...	...
Begoniaceae	800	...	1
Berberidaceae	200	29	4
Betulaceae	100	...	4
Bignoniaceae	750	2	33
Bombacaceae	140	...	11
Boraginaceae	2,000	18	26
Bromeliaceae	1,600	...	9
Bruniaceae	75	...	...
Burmanniaceae	60	...	...
Burseraceae	600	1	7
Buxaceae	50	3	2
Cactaceae	1,500	15	2
Callitrichaceae	25	...	...
Calyceraceae	40	...	...
Calycanthaceae	6	4	...
Campanulaceae	1,500	15	2
Canellaceae	2	...	1
Cannaceae	50	...	1
Capparidaceae	700	6	10
Caprifoliaceae	275	1	11
Caricaceae (2)	40	1	...
Caryophyllaceae (3)	2,100	...	3
Casuarinaceae	50	...	8
Celastraceae	500	10	22
Centrolepidaceae	32	...	...
Chenopodiaceae	1,400	12	22
Chlaenaceae	25	...	...
Chloranthaceae	40	...	...
Cistaceae	175	...	2
Clethraceae	30	...	1
Clusiaceae	400	...	...
Cochlospermaceae	25	...	3

TABLE I (*Continued*)

Species	Total	Alkaloids Pos.	Alkaloids Neg.
Combretaceae	500	2	19
Commelinaceae	600	...	5
Compositae	20,000	82	115
Connaraceae	410	...	1
Convolvulaceae	1,200	4	15
Cornaceae (4)	112	5	4
Crassulaceae	800	2	3
Cruciferae	2,500	5	3
Cucurbitaceae	850	5	10
Cunoniaceae	240	3	10
Cycadaceae	100	...	1
Cyclanthaceae	45	...	...
Cyperaceae	3,200	...	2
Cyrillaceae	5	...	1
Dichapetalaceae (5)	125	1	1
Dilleniaceae	275	...	8
Dioscoreaceae (6)	650	6	54
Dipsacaceae	160	2	...
Dipterocarpaceae	350	...	...
Droseraceae	90	...	...
Ebenaceae	325	...	16
Elaeagnaceae	45	5	5
Elaeocarpaceae	125	...	9
Elatinaceae	30	...	1
Epacridaceae	350	...	8
Ericaceae	1,900	1	6
Eriocaulaceae	600	...	...
Erythroxylaceae	205	9	2
Eucommiaceae	2	...	2
Euphorbiaceae	7,300	13	73
Eupomatiaceae	2	...	2
Fagaceae	600	...	4
Flacourtiaceae (7)	850	3	23
Flagellariaceae	8	...	1
Fouquieriaceae	7	...	6
Frankeniaceae	34	...	2
Gentianaceae	800	6	1
Geraniaceae	850	2	3
Gesneriaceae	1,200	1	...
Globulariaceae	23	...	...
Gnetaceae	45	7	3
Goodeniaceae	300	...	11
Gramineae	5,000	10	16
Guttiferae (8)	750	...	14
Haemodoraceae	35	...	1
Haloragaceae	100	...	3
Hamamelidaceae	100	...	5
Hernandiaceae	25	3	2
Himantandraceae	2	1	...
Hippocastanaceae (9)	49	...	...
Hippocrateaceae	150	...	3
Humiriaceae	20	...	...
Hydrocharitaceae	90	...	...
Hydrophyllaceae	265	...	2
Icacinaceae	225	...	5

TABLE I (*Continued*)

Species	Total	Alkaloids Pos.	Alkaloids Neg.
Iridaceae	1,500	...	14
Juglandaceae	60	...	3
Juncaceae	315	...	...
Juncaginaceae (10)	20	...	...
Labiatae	3,200	8	22
Lardizabalaceae	20	...	...
Lauraceae	1,100	25	24
Lecythidaceae	130	...	2
Leguminosae (11)	13,000	222	412
Lemnaceae	25	...	...
Lentibulariaceae	260	...	...
Liliaceae (12)	4,000	30	190
Linaceae	200	...	1
Loasaceae	250	...	...
Loganiaceae	800	24	9
Loranthaceae	1,100	2	9
Lythraceae	475	...	11
Magnoliaceae	100	3	2
Malesherbiaceae	30	...	...
Malpighiaceae	850	4	11
Malvaceae	1,500	3	26
Marantaceae	350	...	...
Marcgraviaceae	100	...	...
Martyniaceae	16	...	1
Melastomataceae	4,000	...	2
Meliaceae	800	3	26
Melianthaceae (13)	38	...	...
Menispermaceae	400	42	3
Monimiaceae	350	12	9
Moraceae	1,000	3	24
Moringaceae	10	...	1
Musaceae	150	...	2
Myoporaceae	110	2	5
Myricaceae	40	...	2
Myristicaceae	260	...	2
Myrsinaceae	1,000	...	9
Myrtaceae	3,000	1	67
Najadaceae	40	...	...
Nepenthaceae	60	...	...
Nolanaceae	60	...	...
Nyctaginaceae	250	2	5
Nymphaeaceae	90	4	...
Ochnaceae	375	...	2
Olacaceae	150	...	3
Oleaceae	500	6	30
Onagraceae	650	...	7
Orchidaceae	17,000	4	3
Orobanchaceae	140	...	1
Oxalidaceae	1,000	...	3
Palmae	4,000	1	51
Pandanaceae	300	...	3
Papaveraceae (14)	675	69	1
Passifloraceae	600	...	5
Pedaliaceae	50	...	...
Penaeaceae	25	...	...

TABLE I (*Continued*)

Species	Total	Alkaloids Pos.	Alkaloids Neg.
Philydraceae	4	...	2
Phytolaccaceae	125	3	2
Pinaceae (15)	210	1	22
Piperaceae	2,000	11	3
Pittosporaceae	200	...	16
Plantaginaceae	200	...	3
Platanaceae	8	...	1
Plumbaginaceae	300	...	2
Podostemaceae	100	...	...
Polemoniaceae	265	...	1
Polygalaceae	700	1	3
Polygonaceae	800	5	17
Pontederiaceae	28	...	...
Portulacaceae	500	...	2
Potamogetonaceae	120	...	...
Primulaceae	800	...	...
Proteaceae	1,200	...	28
Punicaceae	2	1	...
Pyrolaceae (16)	32	...	1
Quiinaceae	20	...	...
Rafflesiaceae	22	...	...
Ranunculaceae	1,500	58	4
Rapateaceae	25	...	...
Resedaceae	70	...	...
Restionaceae	250	...	...
Rhamnaceae	550	3	16
Rhizophoraceae	70	...	3
Rosaceae	3,200	2	40
Rubiaceae	5,000	53	76
Rutaceae	1,300	74	99
Sabiaceae	65	...	...
Salicaceae	340	...	4
Santalaceae	250	3	3
Sapindaceae (17)	1,100	3	54
Sapotaceae	600	4	21
Sarraceniaceae	14	...	...
Saxifragaceae (18)	1,200	4	11
Scrophulariaceae	3,000	...	10
Simaroubaceae	200	4	11
Solanaceae	2,200	84	22
Sonneratiaceae	12	...	1
Sparganiaceae	20	...	1
Staphyleaceae	24	...	...
Stemonaceae	29	4	...
Sterculiaceae	750	3	24
Stylidiaceae (19)	125	...	3
Styracaceae	120	...	1
Symplocaceae	300	1	4
Taccaceae	30	...	...
Tamaricaceae	100	...	3
Taxaceae	13	3	...
Theaceae (20)	500	1	2
Theophrastaceae	60	...	1
Thymelaeaceae	500	1	11
Tiliaceae	400	...	15
Tremandraceae	30	...	1
Trigoniaceae	26	...	...

TABLE I (*Continued*)

Species	Total	Alkaloids Pos.	Alkaloids Neg.
Triuridaceae	40	...	...
Tropaeolaceae	50	...	...
Turneraceae	105	...	...
Typhaceae	15	...	1
Ulmaceae	150	1	8
Umbelliferae	2,900	3	30
Urticaceae	600	1	9
Valerianaceae	370	1	...
Velloziaceae	170	...	1
Verbenaceae	2,600	6	38
Violaceae	850	1	4
Vitaceae	600	...	12
Vochysiaceae	80	...	...
Winteraceae	90	...	2
Xyridaceae	200	...	1
Zingiberaceae	1,400	...	3
Zygophyllaceae	200	3	3
Total	191,891	1,220	2,598

The following families, sometimes listed separately, are included in, or are synonymous with, the families given under the corresponding number: 1. Agavaceae; 2. Papayaceae; 3. Illecebraceae; 4. Alangiaceae, Garryaceae, Nyssaceae; 5. syn. Chailletiaceae; 6. Petermanniaceae; 7. Bixaceae; 8. Hypericaceae; 9. Aesculaceae; 10. syn. Scheuchzeriaceae; 11. Papilionaceae; 12. Philesiaceae, Trilliaceae; 13. syn. Bersamaceae; 14. Fumariaceae; 15. Taxodiaceae; 16. syn. Monotropaceae; 17. syn. Akaniaceae; 18. Escalloniaceae; 19. syn. Candolleaceae; 20. syn. Ternstroemiaceae.

Scytopetalaceae, 10
Stachyuraceae, 5–6
Stackhousiaceae, 2
Thelygonaceae, 2
Tovariaceae, 2
Trapaceae, 1
Trochodendraceae, 1

A generic table, published in processed form as a supplement to the present article (31), lists only those for which there is alkaloid information. Even so, the list has 1434 names, of which 519, or 36%, contain alkaloids. It may be obtained by writing to the United States Department of Agriculture, Eastern Utilization Research Branch, Philadelphia 18, Pennsylvania.

Where to Look for More Alkaloids

Taking a bird's-eye view of Table I, several items stand out. In the most-looked-into large families (Amaryllidaceae and Rutaceae), only 13% of the species have been examined. In general it is about 2%. Of 283 families (235 in the Table, 48 listed above), 99 of them, with 5700 species, have received no attention as to alkaloids. The following 12 rather large families have just been touched (the first figure is the number of species, the second the percentage of them for which there is alkaloid information):

Caryophyllaceae, 2100, 0.1
Compositae, 20,000, 1.0
Convolvulaceae, 1200, 1.5
Cruciferae, 2500, 0.3
Cyperaceae, 3200, 0.06
Ericaceae, 1900, 0.3
Gesneriaceae, 1200, 0.08
Gramineae, 5000, 0.3
Labiatae, 3200, 1.0
Melastomataceae, 4000, 0.05
Oxalidaceae, 1000, 0.3
Scrophulariaceae, 3000, 0.3

At the other extreme are five families which have been most examined:

Amaryllidaceae, 1300, 13
Berberidaceae, 200, 16
Menispermaceae, 400, 10
Pinaceae, 210, 10
Rutaceae, 1300, 13

Incidence of Alkaloid-Bearing Species

We know of only two sets of data in which both positive and negative species are listed. Webb handled 1793 species; 11% of these were positive. Our laboratory has screened about 1500 species; 5% of them gave positive tests for alkaloids. These are gross figures, of course, and embody all the known variables, such as plant part, age, locality, conditions of growth. The above per-

centages might be higher if all plant parts under all conditions had been tested. We believe it safe to say that five to ten percent of flowering plant species contain alkaloids.

A study of the supplementary table of genera discloses some other points of interest. Of the 1300 genera, 213 are large, containing 100 or more species. The largest are *Senecio* (Compositae) with 2000; *Astragalus* (Leguminosae) with 1600; *Solanum* (Solanaceae) with 1225; and nine others with 600 to 800. Some genera of note are:

Aconitum (Ranunculaceae), 110 species, 31 tested, all positive
Corydalis (Papaveraceae), 140 species, 26 tested, all positive
Lupinus (Leguminosae), 150 species, 22 tested, all positive

At the other extreme are some which gave all negative tests:

Agave (Amaryllidaceae), 275 species, 70 tested
Ficus (Moraceae), 800 and 16
Goodenia, 100 and 6
Hibbertia (Dilleniaceae) 100 and 5
Melaleuca (Myrtaceae) 100 and 7
Plectronia (Rubiaceae) 110 and 7
Terminalia (Combretaceae), 120 and 13
Yucca, 30 and 29

The table will be a guide to alkaloid hunters on a genus basis.

Where are the best prospects for alkaloid hunting? Using the data in Table I, this question can be approached from at least two viewpoints. Considering the size of the families and the proportion of positive species to date, the following would seem promising:

Amaryllidaceae	Papaveraceae
Boraginaceae	Ranunculaceae
Campanulaceae	Rubiaceae
Compositae	Rutaceae
Leguminosae	Solanaceae
Liliaceae	

Considering the size of the family and the paucity of information on them, pioneering work could be done in the following:

Acanthaceae	Labiatae
Cactaceae	Loranthaceae
Caryophyllaceae	Melastomataceae
Cruciferae	Myrsinaceae
Cyperaceae	Orchidaceae
Ericaceae	Oxalidaceae
Euphorbiaceae	Piperaceae
Gesneriaceae	Saxifragaceae
Gramineae	Zingiberaceae

Other considerations come in, of course, such as the availability of the family to the hunter. Furthermore, if the hunter has strictly in mind the ultimate growing of the alkaloid plant for commercial use, he would avoid some of the families named.

Still another viewpoint was submitted by McNair (14). Since electrolytes, including nitrogen compounds, are far higher in herbs than in trees and shrubs, he postulates that the law of mass action would indicate a greater number of organic compounds formed in herbs than in trees. After surveying the information available in 1941, he states: "Alkaloids have been found in three times as many herb families as tree families (19 vs. 6). The average molecular weight of alkaloids from tropical trees is much lower than that from tropical herbs". From this viewpoint the herbaceous families in the above list would offer the best hunting.

In the Gramineae eight alkaloids have already been found in 26 species examined. How many others will be detected in the rest of the 5000 species?

Nor is the hunting restricted to the flowering plants. Alkaloids have already been found in six families of fungi and in four of ferns. The ergot alkaloids have long been important in medicine.

Apparently the alkaloid hunter is not

entirely dependent on fresh plant material. Webb (28) was able, within certain limitations, to use herbarium material for qualitative tests.

The above discussion concerns the search for new alkaloid-bearing plants, irrespective of the nature of the alkaloids. When it comes to looking for a particular alkaloid, or a particular group of them, the information to date may or may not be of help, since there are examples in both directions. Thus nicotine is traditionally the alkaloid of *Nicotiana* (Solanaceae), but it has also been found in *Eclipta alba* (Compositae), *Asclepias syriaca* (Asclepiadaceae) and *Sedum acre* (Crassulaceae). Anabasine has been found in *Anabasis aphylla* (Chenopodiaceae) and in *Nicotiana glauca*. The berberine type of alkaloids occurs in six families. On the other hand, lycorine occurs only in the Amaryllidaceae; and since it has already been found in 14 genera and 21 species, one would expect to find it in many other places within the family, but probably not outside. Strychnine and brucine apparently occur in just one genus, *Strychnos* (Loganiaceae). Finding them in other places would appear to be highly unlikely; in fact it would be an event.

Within our present knowledge alkaloids occur singly in about half of the species containing them. In the rest, several may be found. In some cases the plant metabolism seems to run wild and turns out many closely related forms. For example, *Papaver somniferum* (Papaveraceae) has 25; each of eight species of *Erythroxylon* (Erythroxylaceae) has 14; *Corydalis tuberosa* (Fumariaceae) has about 17; *Holarrhena antidysenterica* (Apocynaceae) has 16.

Summary

A study was made of present activities in the field of alkaloids. Some surveys for alkaloid-bearing plants are made on a regional basis, as in Australia, Russia, Borneo and the Argentine. Other surveys concern particular families or genera. These surveys involve the search for new sources of known alkaloids, and for new alkaloids, followed by a study of their structure and their physiological properties.

Through 1952 some 950 alkaloids have been isolated and named, and in most cases their structures determined. These have been found in 98 families, 537 genera and 1200 species. A table of the 235 major plant families is given, showing for each family the total number of species and the number of species on which there is alkaloid information, either for its presence or absence. A supplementary table by genera, giving the same information, has been prepared and is available as a separate in processed form.

It is suggested that these tables may be of use to present or prospective alkaloid hunters. They indicate some 29 families where attention could be concentrated, either because of the size of the family and the known occurrence of alkaloids in them, or because they are large and almost entirely unexplored.

In general, alkaloids occur in five to ten percent of all species. The incidence is much higher in some families, much lower in others. The picture may change with more research, since there is a record of the presence or absence of alkaloids in only two percent of the 191,000 known species of flowering plants.

Literature Cited

1. Arthur, H. R. A phytochemical survey of some plants of North Borneo. [Private communication].
2. Bertho, Alfred. Kurchi-Alkaloide. VIII. Über Conessin und Apo-conessin. Über Conkurchin. Ann. Chemie 573: 210–219. 1951.

3. Chatterjee, R., and Guha, M. P. Studies on *Mahonia* genus. IV. *M. leschenaultii* (Walli) Takeda, *M. manipurensis* Takeda, and *M. sikkimensis* Takeda. Jour. Am. Pharm. Assoc., Sci. Ed. **40**: 229–232. 1951.
4. Claus, Edward P. The relative importance of plant constituents in the taxonomic arrangement of flowering plants. Univ. Pittsburgh, Bull. **37**(3): 1–6. 1941.
5. ———. Taxonomy of the Liliaceae as based on phytoconstituents. Proc. Penna. Acad. Sci. **18**: 24–29. 1944.
6. Codoni, Julio C. Alkaloids in leaves, bark and wood of Argentine forest trees. Argentina Direc. Forest, Publ. Tech. **9**: 3–13. 1947. [Bio. Abst. **23**: 1939].
7. Efros, R. S. [Finding alkaloid-bearing folk-remedy plants in the Trans-Baikal Region]. Farmatsiya **9**(5): 22–23. 1946. [Chem. Abst. **41**: 7673d].
8. Henry, T. A. Alkaloids. Encycl. Brit. (XIV ed.) Vol. 1: 641. 1940.
9. ———. The plant alkaloids. ed. 4. p. 804. 1949.
10. Koniuszy, Frank, and Folkers, Karl. *Erythrina* alkaloids. XX. Apo- and isoapo-β-erythroidine. Jour. Am. Chem. Soc. **73**: 333–335. 1951.
11. Konovalova, R. A., Diskina, B. S., and Rabinovich, M. S. [Alkaloids of some species of the bean family. X. New alkaloids from *Piptanthus nanus*—piptantine and piptamine]. Zhur. Obshchei Khim. **21**: 773–780. 1951. [Chem. Abst. **45**: 9548e].
12. Lamberton, J. A., and Price, J. R. Alkaloids of the Australian Rutaceae: *Acronychia baueri*. IV. Alkaloids present in the leaves. Austral. Jour. Chem. **6**: 66–77. 1953.
13. Lazur'evskii, G. V., and Sadykov, A. [Investigation of the central Asiatic plants for the content of alkaloids. I]. Trudy Uzbekskogo Gosudarst Univ., Sbornik Trudov Khim. **15**: 182–196. 1939. [Chem. Abst. **35**: 4154].
14. McNair, J. B. Plant forms, the law of mass action and the production of alkaloids, cyanogenetic and organic sulphur compounds. Am. Jour. Bot. **28**: 179–184. 1941.
15. Manske, Richard H. F., and Ashford, Walter R. Alkaloids of Fumariaceous plants. XLVII. The structure of coreximine. Jour. Am. Chem. Soc. **73**: 5144–5145. 1951.
16. ——— and Holmes, H. L. The alkaloids. 4 vols. 1950, 1952, 1953, 1954.
17. Massagetov, P. S. [Searching for Alkaloid-bearing plants in Middle Asia in 1945]. Farmatsiya **9**(3): 22–30. 1946. [Chem. Abst. **42**: 2728].
18. Novelli, Armando, and Orazi, Orfeo O. [Alkaloids isolated from Argentine plants]. Rev. Farm. (Buenos Aires) **92**: 109–118. 1950. [Chem. Abst. **45**: 6349d].
19. Ribas, Ignacio, and Costa, Luis. Papilionacea alkaloids. XIII. Alkaloids of *Adenocarpus commutatus*. Ann. Pharm. Franc. **10**: 54–61. 1952. [Chem. Abst. **46**: 6795i].
20. Tomita, Masao, and Kusuda, Fuyuki. Alkaloids of Menispermaceae. XCV. Alkaloids of Cocculus laurifolius. Jour. Pharm. Soc. Japan **72**: 793–796. 1952. [Chem. Abst. **47**: 6431a].
21. ——— and Nakano, Tatsuhiko. Alkaloids of Magnoliaceous plants. IV. Alkaloids of *Magnolia salicifolia*. Jour. Pharm. Soc. Japan **72**: 281–282. 1952. [Chem. Abst. **47**: 1628b].
22. ———, Inubushi, Yasuo, and Mizoguchi, Noboru. Alkaloids of Berberidaceous plants. VI. Alkaloids of *Mahonia japonica*. Jour. Pharm. Soc. Japan **73**: 776. 1953. [Chem. Abst. **47**: 10806e].
23. Turcotte, François, Leduc, Raymond, and Marion, Leo. Papilionaceous alkaloids. XX. *Lupinus wyethii* S. Wats and *Baptista versicolor* Lodd. Canad. Jour. Chem. **31**: 387–390. 1953.
24. Wall, M. E., Krider, M. M., Krewson, C. F., Eddy, C. R., Willaman, J. J., Correll, D. S., and Gentry, H. S. Steroidal sapogenins. VII. Survey of plants for steroidal sapogenins and other constituents. Jour. Am. Pharm. Assoc., Sci. Ed. **43**: 1–7. 1954.
25. ———, ———, ———, ———, ———, ———, ———, and ———. Steroidal sapogenins. XIII. Supplementary table of data for steroidal sapogenins. VII. U. S. Dept. Agr., East. Util. Res. Branch, AIC-363 [processed]. 1954.
26. Webb, L. J. Guide to the medicinal and poisonous plants of Queensland. Council Sci. & Ind. Res. (Australia), Bull. 232. 1948.
27. ———. Australian phytochemical survey. I. Commonwealth Sci. & Ind. Res. Org. (Australia), Bull. 241. 1949.
28. ———. Australian phytochemical survey. II. Commonwealth Sci. & Ind. Res. Org. (Australia), Bull. 268. 1952.
29. Wehmer, C. Die Pflanzenstoffe. Zweite Auflage, 2 vol. 1929, 1931. Erganzungsband. 1935, pp. 244.

30. White, E. P. Alkaloids of the Leguminosae. XXII. Legumes examined for alkaloids — additions and corrections. New Zeal. Jour. Sci. & Tech. **33B**(1): 54–60. 1951.
31. Willaman, J. J., and Schubert, Bernice G. Alkaloid hunting. Supplemental table of genera. U. S. Dept. Agr., East. Util. Res. Branch ARS-73-1. 1955.
32. Ynusov, S., and Abubakirov, N. K. Alkaloids of the Ranunculaceae Family. V. Alkaloids of *Delphinium oreophilum*. Zhur. Obschei Khim. **21**: 967–973. 1951. [Chem. Abst. **46**: 516g].

Utilization Abstract

Sesame. Seed of sesame (*Sesamum indicum*), an herbaceous crop growing up to five feet in height, is one of the world's oldest sources of edible oil. Before World War II annual production of the oil amounted to about three billion pounds, the bulk of it in China, India and Burma. The crop is grown more or less extensively also in Manchuria, the Anglo-Egyptian Sudan, Nigeria, Turkey, Greece, the Soviet Union and Latin America. In addition to furnishing edible oil in these regions, the whole seed is relished in the Orient and Africa in a wide variety of human foods. Ninety percent or more of the total production is used locally; only about 8% of it formerly entered world trade, and in recent years the amount has decreased.

United States imports of the seed have varied from 146 million pounds in 1934 to slightly more than two million pounds in the war year 1944. Formerly most of these imports came from China; today Latin American countries are the principal suppliers to the U. S. The chief market for whole seed in this country is in the baking industry, where one-third to two-thirds of total consumption serves as topping for bread and rolls, the form in which the seed is most familiar to the American public. Sesame oil expressed from the remainder is used as a salad or cooking oil, in shortening and margarine, and in the manufacture of soap. Minor uses are as a fixative in the perfume industry and as a carrier for fat-soluble substances in pharmaceuticals. One of the minor constituents of sesame oil, sesamin, is used for its synergistic effect in pyrethrin insecticides, where addition of a small amount markedly increases the effectiveness of fly sprays.

Sesame has been grown in the southeastern States, primarily as a garden crop, since near the end of the 17th century, and benne (sesame) seed cakes are traditional in those States. Commercial production on a large scale for oil production has not, however, been successful in this country. Two features inherent in strains of sesame available heretofore have accounted for this, namely, lack of uniformity of maturity, and dehiscence, or opening, of the seed capsules in the field, which results in scattering of the seed. The first difficulty was readily remedied by selection of uniformly maturing pure lines from foreign introductions, but not until 1943 was a mutant gene for indehiscent seed capsules discovered. In 1953, for the first time, indehiscent strains were tested in several States, and seed of these non-shattering varieties are not yet available commercially. When they become so it may be possible to harvest sesame mechanically and profitably in the United States, where the high cost of labor renders it unprofitable to harvest the shattering type of the Old World. (M. L. Kinman, *Chemurgic Digest 13*(*2*): *6. 1954*).

JUTE—*Especially as Produced in West Bengal*

This important plant product, used more extensively, probably, than any other vegetable fibre except cotton, was long a monopoly product of Bengal. Division of that land in 1947 between India and Pakistan created production and employment problems respecting this crop, the solution of which, from the Indian viewpoint, is discussed in this article, along with an account of the fibre itself, of the plants which furnish it, and of the utilization that has made it an item of world-wide importance.

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Introduction

Jute fibre, native to India and for generations a commercial monopoly product of Bengal, was introduced into world trade through the East India Company by the end of the 18th century. Originally obtained from wild plants but soon subjected to plantation production, this fibre has been produced in Bengal for nearly 200 years on ever increasing quantities of land, until by 1907 an all-time maximum of nearly four million acres were devoted to jute production. The fibre is still a monopoly product of northeastern India and of what today is East Pakistan, for, despite all efforts in recent years to initiate jute-growing in other countries, India and Pakistan continue to produce about 97 percent of the world's supply. The Ganges-Brahmaputra delta remains the true home of jute cultivation.

In 1947, when Bengal was divided into East Bengal, now a part of Pakistan, and West Bengal, now in the Indian Union, jute production suffered badly, and in the ensuing season of 1947–1948, West Bengal produced only 39 percent of the total jute output of the Indian Union. In 1947, immediately after the partition, only 266,000 acres in West Bengal were under jute cultivation, but by 1952–1953, as a result of diverting land from rice cultivation and by reclaiming waste land, 836,000 acres were allotted to jute, an increase of 214 percent within five years. That year jute accounted for about 38 percent of India's total foreign currency and for about 62 percent of her total dollar earnings. In the 1952–1953 season West Bengal produced about 52 percent of India's jute, an increase of 12 percent in five years. Trade in jute during the post-partition years has become a lucrative enterprise in West Bengal.

Details of this recovery, of the jute plants and of the procedure in furnishing the fibre to the markets of the world are the subjects of this account.

The Plants

Taxonomy and General Characteristics. Jute plants belong to the genus *Corchorus* of the family Tiliaceae. *Corchorus* consists of some 40 species distributed throughout the tropics of the world. Eight of them occur in India, but only two (*C. capsularis* Linn. and *C. olitorius* Linn.) are useful as commercial sources of fibre. The remaining six (*C. depressus* Linn., *C. antichorus* Raeusch, *C. fascicularis* Lam., *C. tridens* Linn., *C. trilocularis* Linn., *C. aestuans* Linn.) are wild species rarely used for this purpose.

C. capsularis and *C. olitorius* are herbaceous annuals with straight slender stems; the former attains heights of ten to twelve feet under cultivation, while the latter grows even taller. *C. capsularis* is distinguished from *C. olitorius* by its glabrous leaves, small yellow flowers and rather globular seed pods. The leaves of both are bright green, acuminate and serrated, four to five inches long.

FIG. 1. Flowering spray of one species of jute, *Corchorus capsularis*.

C. capsularis is the more popular of the two cultivated species and accounts for nearly 75 percent of the total acreage

FIG. 2. Plantation of highland jute (*Corchorus olitorius*). (*Photo: K. L. Choudhury*).

under cultivation. This species is preferred for its hardier nature. Unlike *C. olitorius* it grows on both high and low lands, withstands water-logging and can be sown and harvested earlier, so that the cultivator is able to raise a crop of transplanted paddy after the jute harvest in June and July. *C. olitorius*, on the other hand, prefers highlands. Its cultivation is therefore limited because of the general lowland topography of West Bengal. It surpasses *C. capsularis*, however, in resisting stem-rot disease and in yielding a greater quantity of jute (2).

Diseases and Pests. There are several diseases and insect pests which cause considerable damage to jute, especially when plants are young, and they affect the yield of fibre considerably.

The common stem rot is caused by *Macrophomina phaseoli* (Maubl.) Ashby. It affects the plants at all stages of growth and eventually causes death. Timely and careful cultural operations in the growing stage of the plant offer control, namely, clearing and burning diseased material, application of lime, if the soil is acidic, and of potassium sulphate.

Soft rot, caused by *Corticium rolfsii* (Sacc.) Curzi, is a soil-borne disease affecting the collar region of the plant in humid conditions. Rotation with other crops checks it to a great extent.

Fungoid disease in jute is comparatively rare; *C. olitorius* and its red-stemmed varieties are immune. Fungi, however, are the chief destructive agents of jute fibre and of products in storage manufactured from it.

Among the insect pests, the worst are three kinds of caterpillar—Indigo caterpillar (*Laphygma exigua*), Jute semi-looper (*Cosmophila sabulifera*) and hairy caterpillar (*Diacrisia obliqua*). They either attack the leaves and check growth or feed on the apical buds and top shoots. Insecticides, such as lead arsenate, calcium arsenate and lead chromate, as well as 0.5 percent HHG and 0.75 percent DDT, have been proved effective in controlling these pests.

Cultivation

Climatic Requisites. Jute plants flourish best with moderate water supply. They thrive well in rains with moist heat, the optimum temperature being 75° to 95° F., humidity varying from 65 to 90 percent, and during the crop season the maximum temperature rarely exceeding 100° F., with a minimum hardly below 60° F.

In northeastern India the monsoon generally sets in towards the middle of June; until then the crop sown during the previous hot weather period of March to May has to depend entirely upon subsoil moisture and northwestern showers. The pre-monsoon showers are very important and are highly beneficial. Two to three inches of rain during the sowing season followed by occasional showers of one to two inches at intervals of about a week are indispensable for successful growth of the plants. The amount of pre-monsoon rains varies with the localities. In Bengal it amounts to over ten inches, in Bihar to two inches and in Orissa to three inches. Most of the crop of Bihar and Orissa, therefore, has to be sown in June. During the monsoon period there is generally a surplus of rainfall, but for the crop alternate periods of sunshine and moderate rainfall are desirable. Excessive rain, saturating the soil, delays both sowing of seed and their after treatment. Jute plants when nearing full growth are tolerant of water which does not submerge them, but young ones are particularly sensitive to water-logging which checks their growth.

Soil Requisites. Jute grows luxuriantly on loamy soil from which it can absorb rain water in contradistinction to sticky clay which neither absorbs nor parts with its water as readily as loam

or sandy loam. Clayey soil yields a short crop, while a coarse fibre is obtained from sandy loam. Jute fails to grow in water-logged soil.

In West Bengal there are two major types of alluvium—old and new. The new alluvium is generally found near large rivers, especially in their deltas, and is the alluvium soil par excellence. The soils of the major portion of Bengal, west of the Bhagirathi River, belong to the old alluvium. The whole of north Bengal, with the exception of the hills, and all of South Bengal belong to the latter category.

FIG. 3. Plantation of lowland jute (*Corchorus capsularis*). Coconut palms in the background and clusters of arum in the foreground are typical of lowlands in Bengal. (*Photo: K. L. Choudhury*).

Almost the entire crop of jute in West Bengal is cultivated on alluvial soil. The important tracts are situated mostly in deltaic areas at a low altitude and with small gradient. During the monsoons these tracts are flooded, some being temporarily under only a few inches of water, whereas others are submerged to a depth of six feet from June onwards; a few are inundated only in July and August.

The old alluvium becomes very hard during drought and prevents spreading of the roots. This seems to be one of the main reasons for its unsuitability for cultivation of the crop. Jute cannot be successfully grown in salt-impregnated soils.

Soil analysis is hardly a guide for selecting sites for jute cultivation. Nevertheless, the optimum soil ingredients may be presented as in Table I.

An important feature of the jute-growing land in West Bengal is its extremely low altitude, a major portion of it rarely being over 100 feet above sea level. This low elevation is indicative

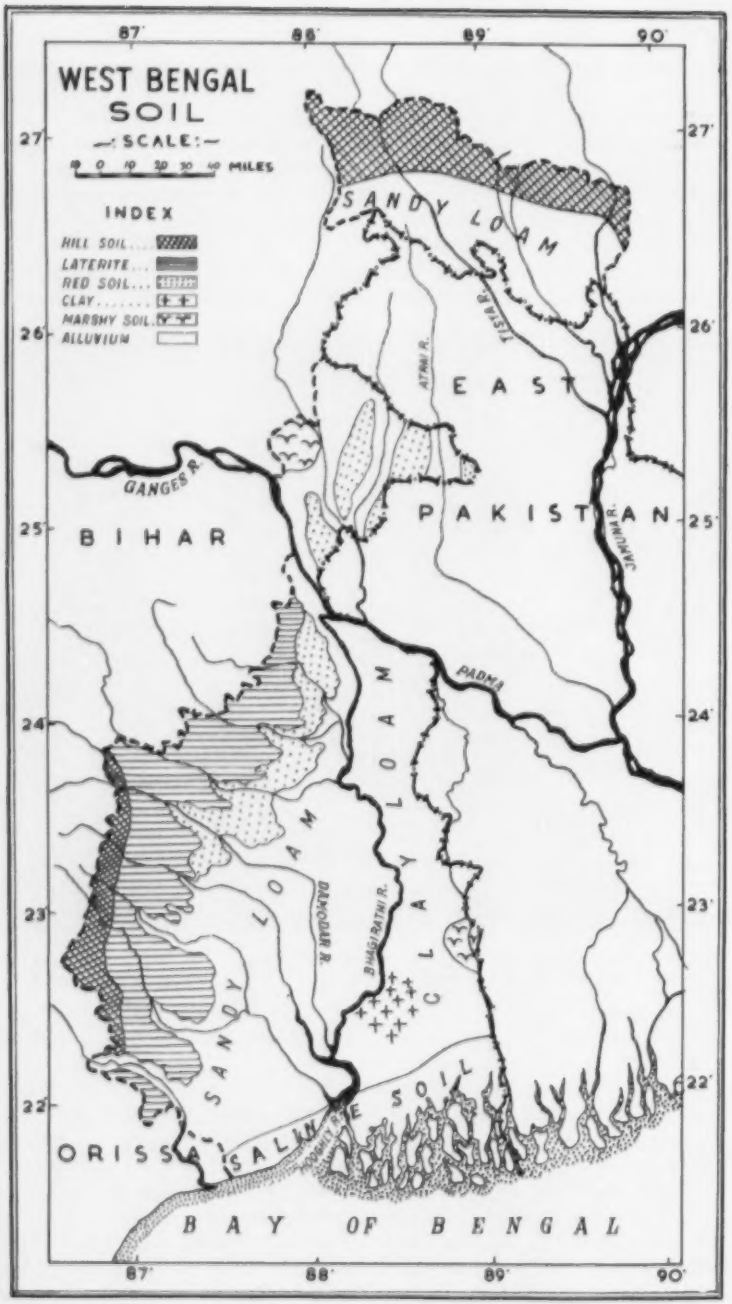

WEST BENGAL
SOIL
SCALE:—
0 10 20 30 40 MILES
INDEX
HILL SOIL
LATERITE
RED SOIL
CLAY
MARSHY SOIL
ALLUVIUM
87°
88°
89°
90°
27°
26°
25°
24°
23°
22°
SANDY LOAM
TISTA R.
ATRAI R.
EAST
PAKISTAN
GANGES R.
BIHAR
JAMUNA R.
PADMA
SANDY LOAM
BAKHOARR.
BHAGIRATHI R.
CLAY
SANDY LOAM
ORISSA
SALINE SOIL
BAY OF BENGAL

FIG. 4.

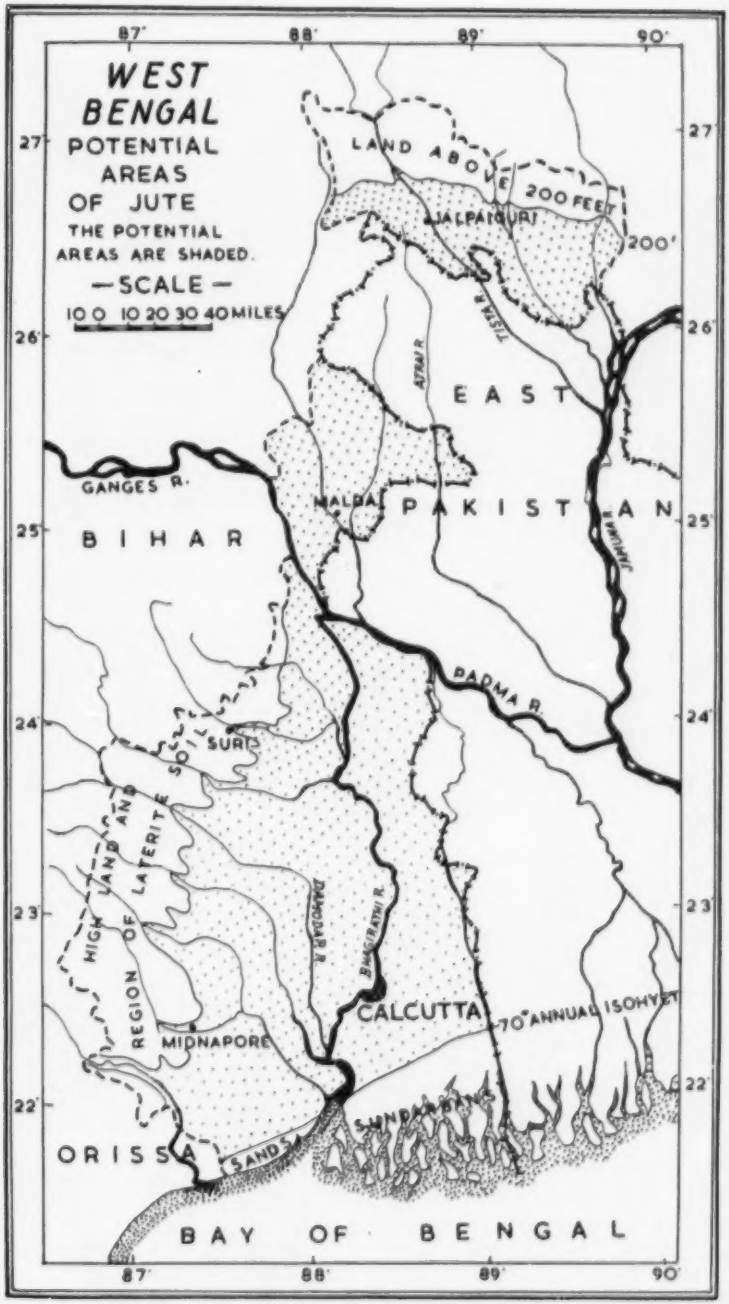

WEST
BENGAL
POTENTIAL
AREAS
OF JUTE
THE POTENTIAL
AREAS ARE SHADED.
—SCALE—
100 10 20 30 40 MILES
87°
88°
89°
90°
27°
26°
25°
24°
23°
22°
LAND ABOVE 200 FEET
JALPAIGURI
200'
TISTA R.
ATRAI R.
EAST
PAKISTAN
GANGES R.
MALDA
BIHAR
JAMUNA R.
PADMA R.
SURI
HIGH LAND AND REGION OF LATERITE SOILS
DAMODAR R.
BHAGIRATHI R.
CALCUTTA
70" ANNUAL ISOHYET
MIDNAPORE
SUNDARBANS
ORISSA
SANDS
BAY OF BENGAL

Fig. 5.

TABLE I

OPTIMUM SOIL INGREDIENTS FOR SUCCESSFUL CULTIVATION OF JUTE (1)

Insoluble silicates	77.0 %
Soluble silicates	0.25%
Ferric oxide	6.0 %
Alumina	3.6 %
Lime	2.0 %
Carbonic acid	2.00%
Manganese	0.10%
Magnesia	0.10%
Potash	0.50%
Soda	0.25%
Organic matter and combined water (nitrogen 0.10%)	8.20%
	100.00%

of the deltaic nature of the typical jute-growing areas.

In short, the jute plant thrives best in moist heat and moderate rainfall. In cultivation it has done best in the sandy alluvial lowlands of the Ganges-Brahmaputra delta. Bengal has such climate and soil, and is, therefore, ideally suited for growing it.

Preparation of Land. Land for sowing is generally prepared after the first rain in February or March. Deep ploughing is essential, and, since the plants have roots which go down about one foot, the land is ploughed and cross ploughed several times. After each ploughing of clay soil, clods of earth are broken by means of harrow. Five to eight ploughings and several ladderings are usually needed. The ladderings clear the soil of weeds and compress it slightly. Soil is thoroughly pulverized to obtain a fine tilth.

Manuring. Owing to the annual deposit of rich flood silts on the land, manuring is almost unnecessary in the river valleys and deltaic regions of West Bengal. In highlands, however, a little manuring is conducive to a good crop. Jute seems not to be an exhaustive crop. Theoretically the crop removes no valuable plant foods, the productive power of jute land remaining the same if leaves and other parts of the plants are allowed to decay in the field after harvesting.

Green manure is especially beneficial, since it influences the physical character of the soil by making stiff clay lighter and allowing light sandy soil to retain a greater amount of moisture. Hence jute is grown particularly well on lands where peas or lentils are cultivated as a second crop or in those areas where rotation of crops is common. Generally cowdung, two to four tons per acre, and wood ashes are used as manures. Decomposed water hyacinth (*Eichhornia crassipes* Solms.) or its ash produces good results. Sometimes artificial fertilizers are also used. Experiments have shown that use of lime and potassium sulphate can remove stem-rot diseases and that ammonium sulphate increases the yield of the fibre. Compost manuring gives a high yield in *C. capsularis*, but in *C. olitorius* the yield cannot be increased beyond a reasonable limit. Application of 20 to 40 pounds of nitrogen per acre gives an increased yield of 30 to 200 percent. Split applications of ammonium sulphate in two or more instalments are more economical than single bulk application.

Selection of Seed. Propagation is by selected mature seed. Selections of good stock from seedlings are made from improved varieties of *C. capsularis* and *C. olitorius*. Of late, the local daisee varieties of seed are being replaced by im-

TABLE II

YIELD PER ACRE OF SEVERAL IMPROVED VARIETIES OF JUTE SEED (4)

Variety	Yield per acre in maunds (82.2 lbs.)
C. capsularis	
C 39-212	30.00
C 41-13	27.32
Tap Red	23.95
Fanduk	21.31
C 42-Kj-34	20.22
C. olitorius	
040-753	26.09
040-632	25.69
039-620	23.86
Chinsura Green (C.G.)	18.76

FIGS. 6 & 7. Typical scenes in marshy land of Bengal where jute stems are retted and fibre extracted from them.

proved strains. Several improved varieties of both species have given good results in different localities under varied conditions.

Some of the improved strains of *C. capsularis* bred by the Government of Bengal are: D 154, which gives higher yield than the local varieties; C 42-Kj-321, which gives high yield with better quality fibre suitable for lowlands; C 39-

212, an early maturing variety also giving high yield; C 41-13, another variety of higher yield by 15–30 percent over local varieties. Of these varieties, D 154 accounts for over 50 percent of the area under this species.

Of the various types under *C. olitorius*, Chinsura Green is most important and popular in respect to cultivation in Bengal, accounting for 75 percent of the area under this species. Other varieties evolved by the Jute Agricultural Research Institute (039-620, 040-632, 040-653) have proved to be more resistant to stem-rot disease and have given higher yields than the variety Chinsura Green.

It thus appears that there is no difficulty in raising the average output of jute by 20 percent or more merely with improved seed. Such seed provides fibre of better quality which matures earlier by three weeks, thus making the land available for a second crop. It has been found that irradiated seeds produce plants of greater height and basal diameter, and consequently much better in yield of fibre.

Damp climate is not productive of good seed, as rains tend to produce mould on the ripening pods which seriously reduces the germination capacity of the seed. West Bengal, with a long rainy season, therefore, is not suitable for furnishing seed; a drier climate like that of Bihar or Uttar Pradesh is ideal for the purpose.

Sowing. In lowlands jute seeds are generally sown from the middle of February to the middle of March to avoid flood and water-logging. In intermediate lands sowings are made from the middle of March to the middle of April, and in highlands from May to the middle of June. Seeds are generally sown broadcast, along and across the field to ensure even distribution; then laddering follows to cover the seeds.

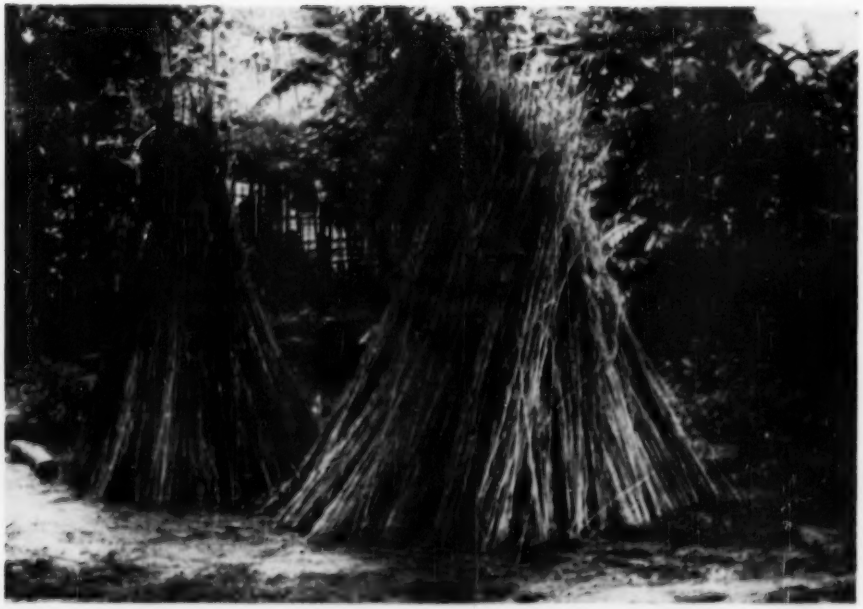
It has been found that line-sowing and inter-culture by the ordinary wheel hoes worked by hand are economical and give good results. Row cropping or line-sowing eliminates wastage of seed, ensures uniformity in spacing and growth, reduces the cost of production by 30 to 40 percent and increases the yield by 250 to 600 pounds per acre over broadcast. Line-sowing by hand, however, remains unpopular with the tillers, as much labour and time are required in this process. In order to eliminate such difficulty, a new hand-pushed drill was devised in 1951 for row cropping of jute on a large scale.

The germination capacity of *C. capsularis* seed is greater than that of *C. olitorius*. In *C. capsularis*, nine to 15 pounds of seed per acre are sufficient to raise a successful crop, while five to 11 pounds are necessary in *C. olitorius*. For seed with exceptionally good germinating power the rate is eight pounds for *C. capsularis* and six pounds for *C. olitorius*.

In the presence of soil moisture, germination takes place within a week. A fresh ploughing of the field and a second sowing with better seed are usually done if the first sowing fails to germinate within ten days.

After-Treatment. Jute plants respond to early weeding, thinning and mulching. When they attain a height of six inches the crop is weeded twice by hand or wheel hoes. The weak seedlings are removed, and the plants are placed in spaces of $4'' \times 6''$ or $6'' \times 6''$. In closer spacing the outturn is obviously less and the growth of the plant is stunted. An increase in spacing usually increases the height and thickness of the stem. Well cared for plants sometimes attain a height of 15 feet or more.

Harvesting. Jute plants require 100 to 130 days from seed germination to maturity, and the crop is harvested from June through October, *C. capsularis* usually earlier than *C. olitorius*. Harvesting may be performed at three stages in



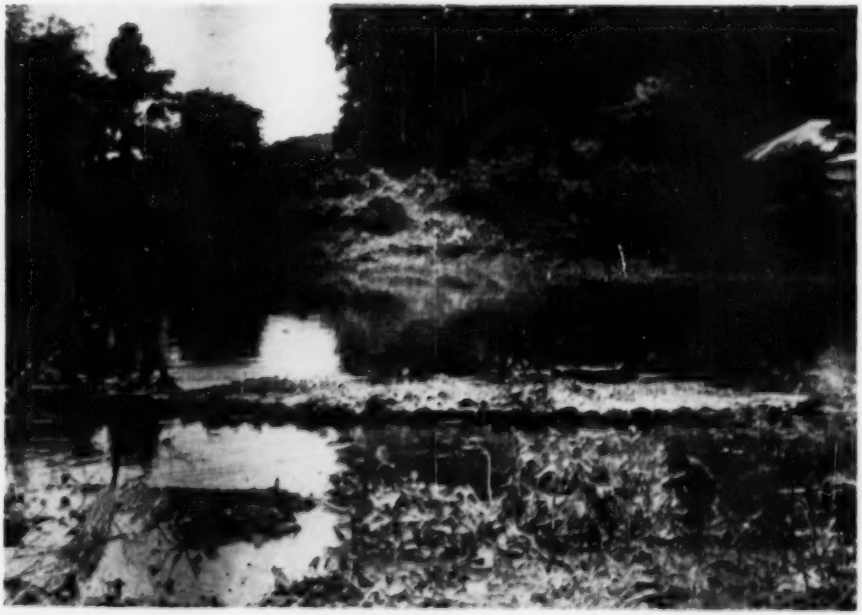


FIG. 8 (*Upper*). Retted jute stems stacked after the cortical fibres have been removed.

FIG. 9 (*Lower*). Typical marshy area in Bengal where jute is commonly retted. (Photo: K. H. Buschmann).

FIG. 10 (*Left*). Moist disintegrate jute fibre, after removal from the jute stems, being dried in the sun.

FIG. 11 (*Right*). Dried jute fibre packed into bales.

the development of the plants: *a*) when the flowers begin to appear; *b*) when the plants are in full flower or fruit; *c*) when all the plants are fully mature. Usually, however, harvesting is carried out at the second stage when about half of the plants have fully developed fruit. The yield then is good and the quality of fibre excellent. At the earlier stage, most plants are immature and the fibre is weak and low in yield; at the later stage the fibre becomes coarse and reddish.

Distribution of Producing Areas. Jute fibre was first exported to the United Kingdom in 1795, where it was recognised as a commodity of trade. There must have been demand for it at the beginning of the 19th century, for in 1855 Royle (6) made a survey of the distribution of jute in different districts of Bengal which then included West Bengal, East Bengal (now in Pakistan) and portions of Bihar, and in 1874 Kerr (3) reported on the cultivation and trade in jute in Bengal. In 1872 the total area under this crop was about 926,000 acres, with an estimated output of 500,000 tons of raw jute. In 1892 the acreage came to nearly 2,000,000 acres with an annual output of about six million bales of 400 pounds each. In 1907 this acreage was reported to be 3,883,200, which appears to have been the largest area ever under jute cultivation.

From 1908 to 1921 jute land varied between 2.4 and 3.4 million acres; during the postwar depression in the year 1921–22, the acreage came down to 1,581,358. Then a period of fluctuation followed, until 1927 when the acreage rose to 3,846,200.

In the early thirties there was a fall of 15–20 percent as compared to the late thirties. But a rise was recorded in 1933, in spite of the low price then prevailing, which was followed by a de-

crease of 18 percent in 1935. Such fluctuations in acreage do not, however, always synchronise with those of the price of raw jute. With a view to harmonising production and price, the government thought it necessary to control cultivation through legislation. Accordingly in 1939 all the jute holdings of Bengal were registered, and further increase in jute acreage was not allowed. But as a result of World War II, the demand for raw jute increased, and to cope with the growing needs of the jute mills then producing burlaps, jute bags, etc., for indispensable war requirements, more lands had to be brought under jute cultivation.

A plot-to-plot survey of undivided Bengal, undertaken by the British Government in 1944–45 to gather agricultural statistics of the State, revealed that jute, with 2,032,600 acres under cultivation, was next to paddy in this respect. Of the 2.5 million acres available as jute-growing land in India, about two million were in Bengal. In 1947 undivided Bengal contributed 82 percent of the total produce of jute in India. In the partition of Bengal, August, 1947, more than 70 percent of the jute-growing lands were ceded to Pakistan, and the jute industry in West Bengal soon faced a scarcity of raw material. Within a short span of five years, however, the acreage of jute lands in West Bengal has been increased considerably by diverting the autumn rice land to jute, by double cropping of winter rice land and by reclamation of waste lands.

The Government of India has undertaken to make the country self-sufficient with respect to jute, since the plant and its fibre span two vital sectors in the country's economy—agriculture and industry. On the agricultural side it provides employment to about a million

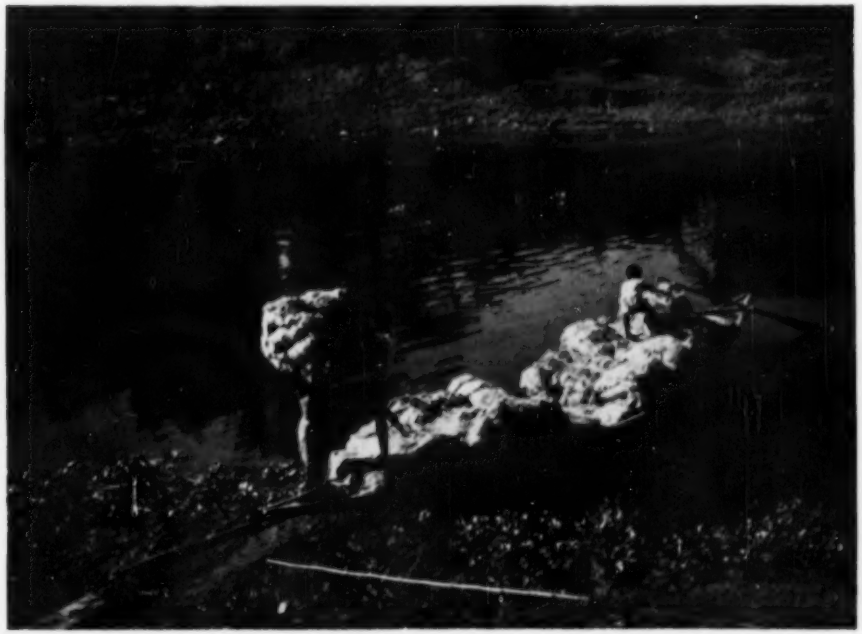


FIG. 12. Native boats, suitable for dead and dying rivers of Bengal, offer one means of transporting jute fibre from areas of production to market places. (Photo: K. Banerjee).

cultivators, on the industrial to about 300,000 workers. Jute also is the largest dollar earner in India. In 1952 it accounted for about 62 percent of the total dollar receipts and about 38 percent of total foreign currency earnings. The need for such income is now specially urgent in view of the finance required for the Five-Year-Plan. Hence the Government of India took every possible step to increase production of one of the most essential agricultural raw materials. Pakistan remained a surplus country in respect to raw jute, but she imposed trade barriers on the free movement of raw jute to India. Hence the price rose from about Rs. 25 per bale in 1946 to more than Rs. 200 per bale in the years after the partition. This price incentive for growing a scarce commodity gave a good start to India's jute self-sufficiency program which was initiated in 1949. But the best stimulant to expansion of area under jute came from the Korean War boom which took prices to about Rs. 500 per bale in 1951.

After the partition, West Bengal was left with only 266,400 acres of jute land which produced 648,000 bales of jute in 1948. By 1953 the area had been increased to 836,000 acres, producing 2,412,000 bales or 51.39 percent of the total Indian output that year. Today West Bengal is the largest jute-growing State in the country.

FIGS. 13 & 14. Another means of transport, whereby 400-pound bales, after being hoisted by a hand-operation contraption, are moved short distances on the heads of laborers.

The jute tracts in West Bengal may conveniently be divided into four zones as follows:

a) The region lying east of the Bhagirathi and Hooghly Rivers, excluding the southern portion of 24 Paraganas district, and the Hooghly and Howrah districts to the west of the river Hooghly.

b) The central region of Malda and West Dinajpur districts.

c) The region of the north, comprising the districts of Cooch Behar, southern Jalpaiguri and southwestern strips of the Darjeeling.

d) Minor regions of sparse cultivation.

The first zone comprises the districts of Murshidabad, Nadia, 24 Paraganas, Hooghly and Howrah. This region is marked by flat alluvial land, humid climate and loamy soil of inexhaustible fertility. It comprises about 60 percent of the total jute acreage of West Bengal. Of the total cropped area, the portion devoted to jute has been increased from about ten percent in 1947 to more than 25 percent. At present the highest concentration is in the Baduria region in the northeast of the 24 Paraganas district, and in Tarakeswar-Poorsoorah region in the district of Hooghly; both regions account for more than 30 percent of the jute land in the total cropped area.

The second zone comprises the districts of Malda and West Dinajpur. The soil of both districts varies in fertility. The Raiganj region on the west, drained by the Nagar and Mahananda, and the Balurghat region on the east, drained by the Atrai, are typical sites of dense jute cultivation. The central part of West Dinajpur and the eastern part of Malda are unsuitable for jute because of the proverbial infertility of the red soil of the region. This zone accounts for about 16 percent of the total jute acreage of West Bengal. The proportion of jute land to the total cropped area has now been increased to 20 percent as against ten percent in 1947.

The third region comprises the districts of Cooch Behar, Jalpaiguri and Darjeeling, with concentration of jute cultivation on the riverine flood plains. The proportion of jute land to the total cropped area varies from region to region. It is five percent in the Rajganj area in Jalpaiguri district, and 30 percent in the Sitalkuchi-Gitaldaha area in southwestern Cooch Behar. This region

FIG. 15. For longer hauls, motor trucks are used as a means of transporting jute fibre prepared for market.

accounts for 13 percent of the total jute tract of West Bengal, and is noteworthy for its yield of superior quality jute.

The fourth zonal division, the area of minor importance, lies throughout the southwestern part of the state. In this area growth of jute is hampered by the hard lateritic soils. The southwestern portion of Midnapore district, however, with the alluvial soil of the Kasai and the Rupnarayan, is notable, as also the Purbasthali region on the Bhagirathi, in the district of Burdwan.

The phenomenal increase of acreage in recent years has occurred in and around those places where jute acreage was the greatest in 1947–48 and earlier. In the northern districts of 24 Paraganas, Nadia and Murshidabad it has amounted to about 300 percent, but in the western districts, such as Midnapore, Burdwan and Birbhum, it has not been so great as in their counterparts east of the Bhagirathi. These facts suggest that the remarkable increase in the eastern districts may be attributed to physical and economic factors, in the western districts to natural factors, and in the northern districts to remoteness of markets and high cost of transportation. The increased acreage in the three regions is

the result principally, however, of high selling prices of raw jute, distribution of seed of improved strains, scientific methods of cultivation replacing primitive methods, ready supply of agricultural labour and suitable climate. Also contributory to the expanded acreage has been the utilisation of autumn paddy land for jute cultivation. In the district of Hooghly alone, more than 90 percent of such land has been transferred to jute. The over-all transfer in West Bengal is estimated at 200,000 acres, but the reclamation of waste land for jute is only 55,000 acres, and double cropping in winter paddy land with jute is estimated to be 100,000 acres.

The so-called " potential area " of jute cultivation in West Bengal is bounded on the north by the 200-foot contour line, on the west by a line joining the towns of Suri and Midnapore; its southern limit is defined by the 70-inch annual isohyetose line; toward the east it extends as far as the boundary between India and Pakistan. Cultivation north of the 200-foot contour line is restricted by the hilly nature of the terrain, by the luxurious deciduous vegetation of the Terai and the Dooars, and by the typical tea soils of the North Bengal region. The area west of the line joining the towns of Suri and Midnapore has been excluded because of its lateritic soils which are rich in oxides of iron and aluminium, poor in silica and almost devoid of colloidal matter. The soils are infertile and difficult to plough. The area south of the 70-inch annual isohyetose line consists of mangrove swamps and of a dense forest known as the " Sundarbans "; the soil, impregnated with salts, is unsuitable for jute cultivation.

The Fibre

Jute fibre is generally known as " pat " in West Bengal. The word " jute " is probably derived from " jhat ", a synonym for " pat ", used in Orissa, a neighboring Province.

Extraction. The fibre is obtained from the cortex of the harvested plants. In its natural state it is associated with a kind of gum which must be fermented and then removed by washing. To accomplish this, bundles of jute are allowed to ferment by being kept under water for a few days. The connecting tissues of the plant are thus decomposed, and the fibres between the stem pith and the outer husks can be removed. The breakdown of the tissues, caused by a combined action of water and micro-organisms, follows a definite sequence, the cambium being the first to be attacked, the thin-walled ray cells and the soft tissues of the phloem the next to disintegrate, and finally the cortex to become disorganized. This process of retting is complete when all the soft tissues are dissolved and the fibre bundles become separated.

Retting water has much to do with the quality of the fibre. In West Bengal jute is generally retted in stagnant water. The fibre obtained from such water is somewhat dark, whereas that of jute steeped in clear water acquires a white shade; in muddy water, the shade is dark grey. In running water the inner bundles rot earlier than the outside bundles, thus producing fibres of uneven quality. In shallow water the lowermost bundles touch the ground, and the colour of the fibre is thus affected. For retting, therefore, deep, stagnant and transparent water is preferred.

The plants take ten to 20 days to ret.

FIG. 16 (*Upper*). Bullock carts are still utilized in Bengal for transporting jute fibre up to distances of 25 miles.

FIG. 17 (*Lower*). Primitive method of ploughing a field in Bengal preparatory for jute cultivation.

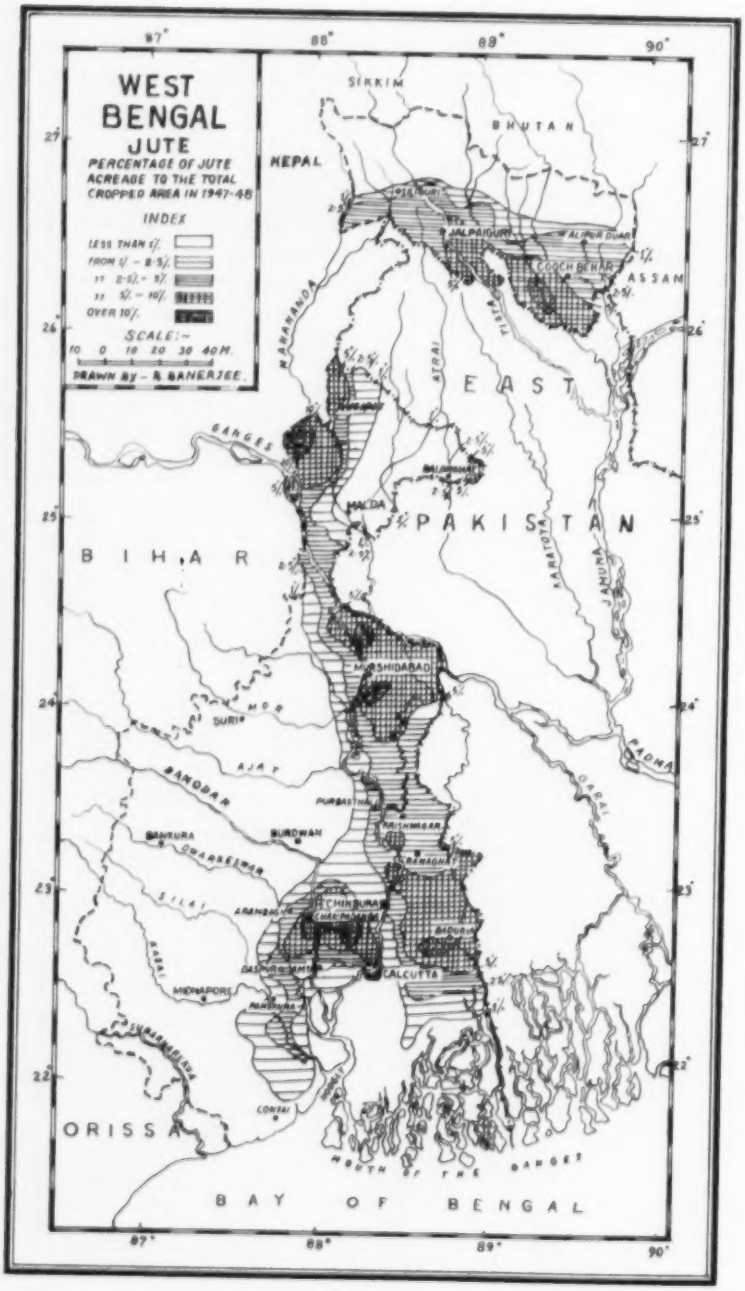

WEST
BENGAL
JUTE
PERCENTAGE OF JUTE
ACREAGE TO THE TOTAL
CROPPED AREA IN 1947-48
INDEX
LESS THAN 1%
FROM 1% - 2·5%
" 2·5% - 5%
" 5% - 10%
OVER 10%
SCALE:-
10 0 10 20 30 40 M.
DRAWN BY - S. BANERJEE.
SIKKIM
BHUTAN
NEPAL
ASSAM
JALPAIGURI
COOCH BEHAR
ALIPUR DUAR
EAST
PAKISTAN
BIHAR
ORISSA
MALDA
MURSHIDABAD
BANKURA
BURDWAN
CALCUTTA
MIDNAPORE
BAY OF BENGAL
MOUTH OF THE GANGES
GANGES
MAHANANDA
TEESTA
ATRAI
KARATOYA
JAMUNA
PADMA
BHAGIRATHI
AJAY
DAMODAR
SILAI
KASAI
87°
88°
89°
90°
27°
26°
25°
24°
23°
22°

FIG. 18.

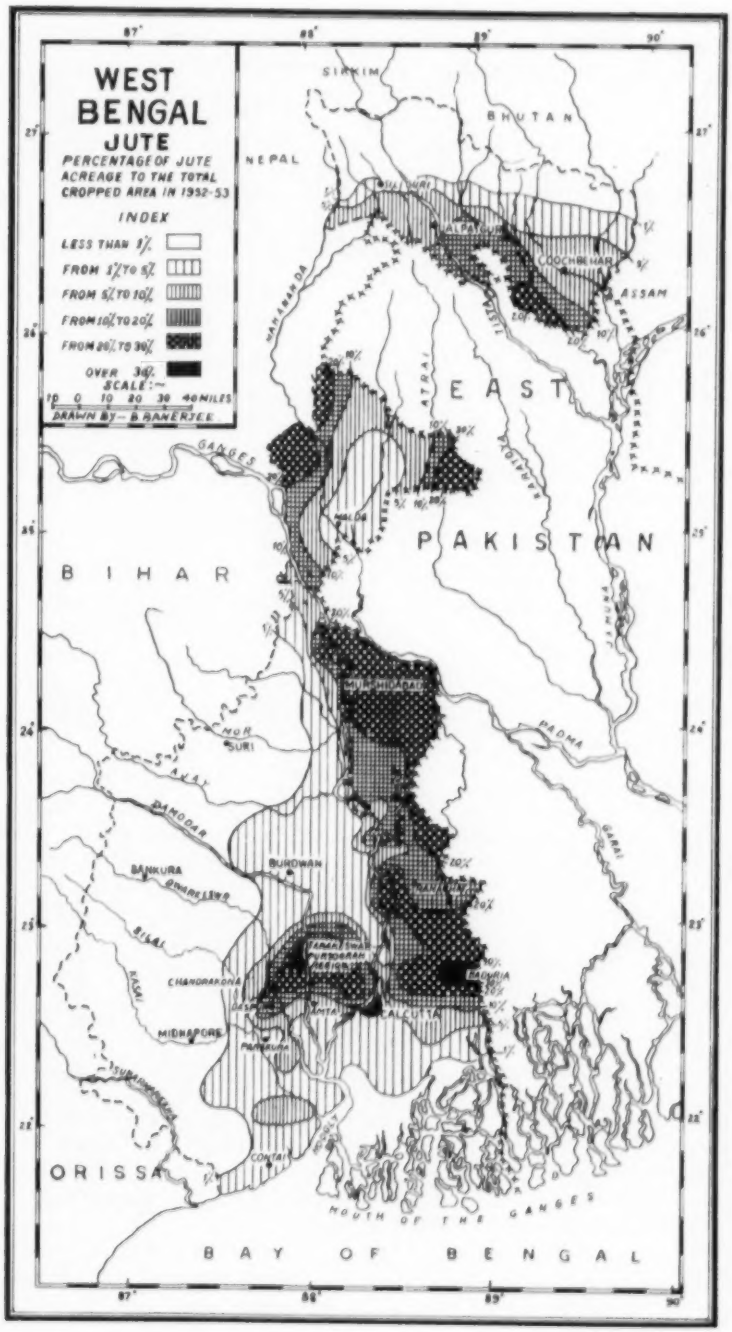

WEST BENGAL
JUTE
PERCENTAGE OF JUTE ACREAGE TO THE TOTAL CROPPED AREA IN 1952-53
INDEX
LESS THAN 1%
FROM 1% TO 5%
FROM 5% TO 10%
FROM 10% TO 20%
FROM 20% TO 30%
OVER 30%
SCALE :-
10 0 10 20 30 40 MILES
DRAWN BY - B BANERJEE
SIKKIM
BHUTAN
NEPAL
ASSAM
COOCHBEHAR
EAST
PAKISTAN
BIHAR
GANGES
PADMA
BURDWAN
BANKURA
MIDNAPORE
CHANDRAKONA
CALCUTTA
ORISSA
MOUTH OF THE GANGES
BAY OF BENGAL

Fig. 19.

The retting period varies with the thickness of the stem, maturity of the plant, the temperature and the water in which the plants are steeped. Over-retting makes the fibre dull and weak. One of the essential factors for fibre quality is a supply of clean water for retting.

To obtain best results in retting, the bundles are made about eight inches in diameter. Moreover, the quicker the retting the better is the quality. Use of ammonium salts and phosphates has been proved to accelerate the process. The dark colour of the fibre results from an interaction between tannic acid in the jute plant and iron in the retting water. To improve retting it has been suggested to press the bark mechanically to ribbons in the field, and then to transport the same to the retting stations to minimise the cost of transport and to reduce the time of retting from three weeks to only three days.

Immediately after retting, small bundles of eight to ten plants are thrashed by a mallet in order to loosen the fibres partially at one end. The fibres thus loosened are then wrapped round the fingers and the stems are jerked forward and backward in the water in order to free the fibres completely from other parts of the stems. The fibres are then washed in running water, water is squeezed out, and the stripped fibres are dried in the sun two to three days before being made into bundles for market. Attempts by mechanical and other means to improve on this simple method of extracting the fibre have failed so far, as they are found to impair the quality of jute and are expensive.

Yield. A good yield of fibre depends on topography, climate and soil as well as on the variety of seed, care of the crop, spacing, condition of the harvest and incidence of disease and insect pests.

The official estimate of the average annual outturn of jute per acre is about 1500 pounds. With favourable weather conditions, an outturn of about 2500 pounds may be expected from seed of improved strains. In order to have maximum yield, the height of the plant should be maximum. Growth is stunted by continued cultivation of the crop year after year in the same field. Hence rotation with leguminous crops is practised in some cases.

The fibre content of mature plants is remarkably constant. It varies between 4.5 and 7.5 percent of the weight of green plants. The thickness of the stem adds more to the fibre content than the height. The degree of the taper also affects the yield, cylindrical stems yielding more fibre than conical ones.

Storage. Proper storage is vital to maintain good quality of fibre. A high percentage of moisture combined with heat encourages fermentation, damaging the fibre, especially in the interior of the bales. Jute fibre is highly hygroscopic. In a dry place and atmosphere, it contains not more than six percent moisture; under humid conditions it absorbs as much as 23 percent moisture. Care is therefore taken to stock jute in a reasonably dry condition.

The cultivators in the villages do not have special warehouses of their own. Their method of storage is very primitive, the jute bundles generally being placed on bamboo shelves in order to avoid direct contact with the earthen floors of the huts.

In primary markets small corrugated iron-roofed huts are used. These huts are sometimes owned by the dealers in raw jute or sometimes they are rented for the jute season. The warehouses in the secondary markets have brick walls with corrugated sheet-iron roofs.

The warehouses in terminal markets of Calcutta are generally made of brick with cement flooring. Most of these mills have solid brick and cement construction throughout and are thoroughly water-tight. They can well accommo-

date 20,000 to 50,000 tons of baled jute. It is estimated that the total storage capacity of the Calcutta jute mills is between 5,500 and 6,500 thousand tons of bales of 400 pounds each. Loose jute fibres are stacked according to grade, preferably in well-ventilated buildings.

The presshouses and warehouses of the merchants engaged in exporting jute to foreign markets are situated on both sides of the river Hooghly. They are extensive, spacious and well built for both baled and loose jute. The approximate capacity of these warehouses of "pucca balers" is 3,500 thousand bales of 400 pounds each.

Jute loses much of its colour and strength if long exposed to weather under primitive storage conditions. The light golden colour gradually darkens, thus making the fibre unfit for certain purposes. It also loses weight as a result of lengthy storage. It has been estimated that Calcutta mills have sometimes suffered a loss of Rs. 4,000,000 by buying jute with absorbed moisture which subsequently lost weight through long storage.

Utilization. As late as the middle of the 19th century, use of jute was insignificant, and at that time it was not so extensively grown as were flax and hemp; the little amount that was cultivated was consumed by the cottage industry in spinning into coarse yarn and cordage. Since the discovery of spinning jute into yarns and the subsequent development of machinery by the earlier part of the 19th century, large quantities of jute goods have been manufactured in Dundee, Scotland, and in the mills of Calcutta, India. Today jute fabrics are well considered as the world's most popular packing material for foodstuffs, minerals, chemicals and many other commodities, for which purposes jute surpasses other industrial fibres in being relatively inexpensive, strong, and resistant to wear and tear. The total consumption of jute goods all over the world today amounts to about 1,500,000 tons annually, the jute mills in India alone manufacturing about a million tons of sacks, bags and burlap clothes. A major portion of the rest is made by the mills in the United Kingdom and on the Continent.

Jute yarns spun from the fibres are classed as "hessians" or "burlaps", "double warp baggings", "twilled sackings" and "tarpaulins". Some of the fabrics manufactured from these yarns are utilized without further processing for wrapping various articles, e.g., furniture, textiles, cordage and ice. Others are cut and used directly in the upholstery and automobile industries. Most of the hessians, however, are made up into sacks or bags of various sizes.

Jute occupies a vital position in world food economy because of the great demand of sacking for agricultural purposes. It is also used for horticultural purposes as screening in protecting plants against wind, sun and frost, and to prevent withering of tea leaves in factories. It forms the base of linoleum and wool carpets, and can itself be converted into inexpensive all-jute carpets with attractive designs. It also enters extensively into roofing felts and wall plastering, into linings in shoes, into clothing as padding and stiffening, and into the production of beach shoes and deck chair cloth. Jute twines are used for binding purposes. Cotton-jute unions are used for covers of deck chairs, mattresses, etc. Jute brattice cloth is required for mine ventilation and is converted into mats, tapestries, table covers, curtains, tents, water-holding stores, theatrical canvas and screens.

In engineering, jute yarns serve as the core of wire ropes, cable fillings, wrappings and braidings. In the chemical industry high quality yarns find use in the production of fuses.

The Indian jute mills produced mil-

lions of yards of jute yarns during the last war, and fabricated parachutes for air-dropping of supplies and equipment. Jute formed the basic fabric for the construction of aeroplane runways.

Raw jute is used by the producers in villages to the minor extent of two and one-half percent; exported, ten percent; and consumed by the mills in Calcutta to the large extent of 88 percent. The mills produce mainly sacking (61 percent), hessian (35 percent) and rope twine (four percent). About 96 percent of hessian is exported and the rest is used at home; 82 percent of sacking and 39 percent of rope twine are exported. The major part of rope twine (61 percent) is consumed at home.

Economics of Jute Production in West Bengal

The rural economy of West Bengal is based on an agricultural system predominately dependent on subsistence farming. The poor cultivators have no sources of income other than their agricultural produce. Hence the prime importance of a money crop to them cannot be overemphasised. Jute is not a consumption crop like paddy, and if it does not bring a lucrative price, the producers have no incentive to grow it. Justification for such an assertion is to be found in a comparison of the acreage under its cultivation with the harvest price as portrayed in Table III.

TABLE III

ACREAGE AND HARVEST PRICE OF JUTE IN WEST BENGAL

Seasons	Acreage under jute	Harvest price of jute in the preceding season, per maund (82.2 lbs.)
1947–48	266,385	Rs. 35–0–0
1948–49	349,905	Rs. 35–0–0
1949–50	498,000	Rs. 42–0–0
1950–51	650,900	Rs. 45–0–0
1951–52	876,100	Rs. 100–0–0
1952–53	836,300	Rs. 60–0–0

TABLE IV

AVERAGE COST OF PRODUCTION OF JUTE PER ACRE IN WEST BENGAL

Cost of ploughing and sowing of seeds @ Rs. 2/– per plough—12 ploughs	Rs. 24–0–0
Cost of thinning and weeding @ Rs. 1/8/– per labour—25 labours	Rs. 37–8–0
Cost of harvesting @ Rs. 1/8/– per labour—18 labours	Rs. 27–0–0
Cost of transportation of jute plants to the place of retting @ Rs. 1/8/– per man—16 men	Rs. 24–0–0
Cost of washing the fibre @ Rs. 4/– per labour—16 labours	Rs. 64–0–0
Miscellaneous expenses	Rs. 3–8–0
(Total cost of ploughing an acre)	Rs. 180–0–0

Increases and decreases in the acreage of jute cultivation generally coincide with rises and declines in the price of jute. Violent fluctuations in price, however, do not help production, for the cultivators are not in favor of either promoting or curtailing their output on the basis of uncertainties. Price booms naturally stimulate production, but if the growers do not realize a fair price to cover their cost of production and a small profit, they are not induced to increase their production, especially on lands of low fertility.

The average production of jute is about 1,500 pounds (i.e., 18 maunds) per acre, and the cost is at the rate of approximately Rs. 10/– per maund (82.2 pounds). In recent years, however, production cost of raw jute has varied between Rs. 8 and Rs. 16/–, and has fluctuated inversely with the incidence of inclement weather, scarcity of retting water, abundance of diseases and pests, and of other factors. It is interesting to note that, of the total cost of production, about 80 percent is spent for human labour, and that of the latter about 40 percent is incurred by weeding operations.

While the average cost of production of jute is Rs. 10/– per maund, that of rice is about Rs. 8/– per maund. If the

TABLE V

PRICE AND ACREAGE OF JUTE AND WINTER RICE IN WEST BENGAL

Seasons	Acreage in thousands of acres			Prices in rupees per maund		
	Jute	Rice	Jute as percent of rice	Jute	Rice	Jute as percent of rice
1947–48	266.4	9345	2.8	35–0–0	25–0–0	140
1948–49	349.9	9144	3.8	42–0–0	25–0–0	168
1949–50	498.0	8442	5.8	45–0–0	25–0–0	200
1950–51	650.9	8637	7.5	100–0–0	30–0–0	333
1951–52	876.1	8278	10.5	60–0–0	30–0–0	200
1952–53	836.3	8801	9.5	25–0–0	25–0–0	100

price of jute increases at the same rate as that of rice, the rice cultivators prefer to devote some of their land to jute. Hence the amount of land under jute as compared with that under rice varies inversely as the ratio of the price of jute to that of rice. That is to say, it is the price of jute relative to that of rice, not the price of jute alone, that governs the extent of the area under jute cultivation.

To assess the economic consequences of the extension of jute acreage on rice land, several factors must be taken into consideration. The result of such diversion is a loss of food to the extent of one ton for every three acres diverted. The financial aspects of this acreage diversion are presented in Tables VI and VII.

TABLE VI

INCOME FROM EXTRA JUTE YIELD ON AUTUMN RICE LAND (5)

Average mill consumption of raw jute for gunnies exported (in 100,000 bales)	Total foreign exchange earned from gunny exports (in 10,000,000 rupees)	Average foreign exchange earned on each bale of raw jute (in rupees)	Average extra yield of jute (in 100,000 bales)	Total foreign exchange earned on the average extra yield of jute (in 100,000 rupees)
48.2	128	267	6.00	1602

India annually earns about 160 million rupees by exporting jute grown on diverted rice land, as a result of which she spends 28.5 million rupees for imported rice in lieu of what could be produced on such land. The result is a

TABLE VII

EXPENDITURE UNDER PURCHASES ACCOUNT OF RICE COMPARED WITH THE PROBABLE YIELD ON THE ADDITIONAL JUTE ACREAGE (5)

Average yield of rice per acre in tons	Extra area under jute (in 100,000 of rupees)	Possible rice yield on acreage shown in the extra area under jute in tons	Average cost of production of imported rice per ton in rupees	Total expenditure of the imported rice which can be grown in the extra area under jute (in 100,000 rupees)
.33	2.00	66,000	432	2.85

profit of some 130 million rupees every year. It should be noted, however, that the cultivators get only an insignificant share of this profit, primarily because of lack of organization, of withholding the crop immediately after harvest for pressing debt obligations, lack of storage facilities and, finally, because they do not have any organization of their own to promote trade directly with the terminal markets.

Literature Cited

1. Choudhury, N. C. Jute and substitutes. 1933. [p. 24].
2. Finlow, R. S. The production of jute. Jour. Text. Inst. **30**: 352. 1939.
3. Kerr, H. C. Report on the cultivation of and trade in jute in Bengal. 1874. [p. 65].
4. Kundu, B. C. Jute, more jute. Jute & Gunny Rev., Ann. Rep. 1952: 114–115.
5. Mukherjee, A. K. Studies in the jute economy of India. Jute Bull. **14**: 374–375. 1952.
6. Royle, J. F. Fibrous plants of India. 1855. [p. 240–252].

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Utilization Abstract

Tyrolean Conifer Oils. In years gone by, Tyrolean natives prepared decoctions from the needles of indigenous conifers for use in baths against rheumatism and similar ailments, and by boiling young sprouts with sugar they obtained a syrup used as a remedy against colds. Less specifically they cut the branches and needles into small pieces, poured boiling water over them, and inhaled the vapours in cases of illness.

The species used were *Pinus pumilio* which yielded oil of dwarf pine (Oleum Pini Pumilionis), known to the natives as "Latschenkiferol"; *Abies alba* which yielded fir oil (Oleum Abietis Albae), known as "Edeltannenol"; *Picea abies* which gave spruce oil (Oleum Pinum Piceae), known as "Fichtennadelol)"; and *Pinus sylvestris* which gave Oleum Pini Sylvestris, or "Kifernadelol".

Of these species, the dwarf pine grows mainly on rocky soil and steep slopes above 6,000 feet elevation where other trees seldom grow. In such desolate, dangerous and fatiguing regions the small needle-covered branches are cut off by workmen, tied in bundles and then carried to distilling installations set up in the mountains as near as possible to the collecting areas. At these distilleries the material is cut into small pieces and distilled by steam during only a few summer months when weather permits.

Formerly all these conifer oils were used almost exclusively for medical purposes, and today this is still true in large part of the oil from dwarf pine. It is listed in the pharmacopoeia of various countries, and has been used for inhalations and embrocations, cough drops and even in injections.

The other oils, those of fir and spruce needles, have found places in the cosmetic, perfume and soap industries. (Unterwerger Brothers, *Perf & Ess. Oil Rec. 46(1): 6. 1955*).

Poisonous Plants of Greece

The distribution, flowering period and abundance of 185 species, growing wild in Greece and injurious to grazing cattle there, are here listed.

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The F.A.O. Report of the Mission to Greece, published in 1947, states that the annual loss of livestock in that country as a result of disease amounts to ten percent of the total capital value of the country's livestock. The authors suggest that of this staggering total, probably two-fifths may be attributed to consumption of plants considered poisonous or at least injurious to livestock. The scarcity of veterinary care in village areas might well mean that minor disturbances in digestion and metabolism accruing from ingestion of harmful plants result in losses ordinarily preventable by medical attention.

Unfortunately Greece has no established research center for veterinary problems of this nature. As a consequence, control of range poisoning plants has received little if any attention; in the F.A.O. report of 1947 mention is not made of this problem, the Ministry of Agriculture has no published reports, and the American Mission has not approached the matter at all.

The authors undertook this work in the hope that the most important information would be summarized and issued as one of the Mutual Security Administration bulletins. Unfortunately the American Educational Foundation in Greece, which sponsored the American author during the term of a Fulbright grant for the school year 1952–1953, did not appreciate the significance of this agricultural project and refused the request for a grant of fifty dollars to cover the cost of typing, photography, etc. An appeal to the Agricultural Section of the American Mission to Aid Greece for the needed funds was never acted upon.

It is hoped that at some time in the future funds will be available to publish and distribute a leaflet, including sketches of the most wide-spread and most important of these plants, among the farmers of Greece, almost all of whom have some stock. Control of the plants presents a major problem, but the sooner a start it made, the sooner will a reasonable amount of control be realized.

The authors are indebted to Mr. Harlond Smith, former Director of the Agricultural and Technical Institute at Delhi, New York, for his cooperation in arranging for this material to be typed and prepared for publication. The authors are also indebted to Miss Eleanor Hertsch, a student at the Institute, for the outline map of Greece reproduced in the text. The plants collected in the study have been deposited in the Weigand Herbarium at Cornell University

Submountain: plains to 1000 feet above sea level.
Mountain: to 3500 feet above sea level.
Subalpine: 3000 to 4800 feet above sea level.
Alpine: 4800 to 5400 feet above sea level.

FIG. 1. Outline map of Greece and its islands, with ecological areas cited in the text referred to by numbers.

1. Polypodiaceae

*1. *Pteridium aquilinum* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Cyclades, Crete and other areas. Submountain and subalpine woods. Frequent. July–September. Perennial.

2. Equisetaceae

*2. *Equisetum arvense* L. Thrace, Macedonia, Thessaly, Attica, Crete, Arcadia, Elis. In fields and damp meadows of low and mountain regions. Rare. March–April. Perennial.

*3. *Equisetum palustre* L. Thrace, Macedonia, Eperus, Attica, Achaia, Elis, Messini. In humid areas of plains and mountain regions. Rare. April–May. Perennial.

4. *Equisetum sylvaticum* L. Thrace, Macedonia, Crete. On irrigated soils and shaded areas. Rare. April–May. Perennial.

*5. *Equisetum telmateia* Ehrh. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Crete, Peloponnesus. In shaded and humid areas of plains and mountains. Rare. March–April. Perennial.

3. Taxaceae

*6. *Taxus baccata* L. Macedonia, Thessaly, Eurytania, Euboea, Achaia, Arcadia, Laconia. Solitary. In woods of mountain and subalpine regions.

4. Gramineae

*7. *Agropyron elongatum* (Host) Beauv. Thrace, Macedonia, Eperus, Thessaly, Cyclades, Crete, Attica, Argolis. Sandy, humid areas near the sea-shore. Frequent. June–July. Perennial.

*8. *Agropyron junceum* (L.) Beauv. Thrace, Macedonia, Ionian Islands, Cyclades, Crete, Attica, Elis. Sandy areas near the sea-shore. Frequent. June–July. Perennial.

*9. *Agropyron litorale* (Host) Dum. Thrace, Macedonia, Attica, Ionian Islands, Achaia, Argolis, Tenos Island. Sandy areas of the sea-shores, on banks of rivers, in weedy fields of plains and mountain regions. Frequent. June–July. Perennial.

*10. *Agropyron repens* (L.) Beauv. Thrace, Eperus, Ionian Islands, Aetolia, Attica, Argolis, Messeni. Stony cultivated fields and weedy places of lowlands and mountain regions. Frequent. June–August. Perennial.

*11. *Bromus tectorum* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Cyclades, Crete and other areas. Barren fields, on walls, along streets, of lower and subalpine regions. Widespread. April–June. Annual.

12. *Holcus lanatus* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Crete, Euboea, Aetolia, Elis, Arcadia, Laconia. Weedy fields, in woods and hollows of ground of lowland and subalpine slopes. Rare. May–July. Perennial.

*13. *Lolium perenne* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Cyclades, Crete. Along roads, sandy grounds, in cornfields of lowland and mountain regions. Widespread. April–July. Perennial.

*14. *Lolium temulentum* L. Thrace, Macedonia, Ionian Islands, Crete, Attica, Euboea, Aiyina Island, Achaia, Argolis, Methana peninsula, Messeni, Laconia, Corinth. Cultivated fields. Widespread. May–July. Annual.

*15. *Sorghum halepense* (L.) Pers. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Cyclades, Crete.

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Aetolia	13	Corinth	7	Kavalla	38	Photis	11
Aiyina	45	Drama	37	Khalkidhiki	35	Poros	46
Akarnania	12	Elias	5	Kilkis	33	Preveza	22
Arcadia	3	Euboea	9	Komotini	40	Pthiotis	17
Argolis	4	Eurytania	16	Kozani	27	Thasos	41
Arta	21	Evroy	42	Laconia	1	Thessalonika	34
Attica	8	Florina	29	Larissa	19	Trikkala	23
Boeotia	10	Igoumenitsa	25	Levkas	44	Varia	31
Cephalonia	15	Ionnina	24	Makrinitsa	18	Xanthe	39
Cerres	36	Kardhitsa	20	Messini	2	Zante	14
Chios	43	Kastoria	28	Mittilini	47		

Cultivated fields, rocky soil of lowland and submountain regions. Rare. June–August. Perennial.

*16. *Sorghum vulgare* Pers. Cultivated fields, on rocky soils of lower and submountain regions. Rare. June–August. Perennial.

5. Araceae

17. *Acorus calamus* L. Laconia. Aquatic. Very rare. June–July. Perennial.

*18. *Arum italicum* Mill. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Crete. Shady places of lowland and subalpine regions. Frequent. April–May. Perennial.

*19. *Arum maculatum* L. Thessaly, Euboea, Attica, Peloponnesus, Aegean Islands. Mountains and subalpine shaded areas. Very rare. May. Perennial.

6. Liliaceae

*20. *Colchicum autumnale* L. Thrace, Macedonia, Thessaly, Aetolia, Peloponnesus. Humid areas, rocky mountainous areas and subalpine regions. Rare. July–September. Perennial.

21. *Convallaria majalis* L. Macedonia, Eperus, Thessaly, Attica, Laconia. In mountain woods. Very rare. May–June. Perennial.

*22. *Ornithogalum umbellatum* L. Thrace, Macedonia, Attica, Ionian Islands, Cyclades, Arcadia, Messeni. Cultivated fields, rocky soils of lowlands and sub-alpine regions. Frequent. March–April. Perennial.

23. *Veratrum album* L. Thessaly, Pindos Mts., Eperus (on Mt. Peristeri), Attica. In subalpine and alpine pasture fields. Rare. June–August. Perennial.

7. Cannabinaceae

*24. *Cannabis sativa* L. Thrace, Macedonia. Cultivated. Rare. Annual.

*25. *Humulus lupulus* L. Thrace, Macedonia, Thessaly, Attica, Eurytania, Euboea, Arcadia, Laconia. In hedges and shrubs of lowland and mountain regions. Rare. June–August. Perennial.

8. Urticaceae

*26. *Urtica dioica* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Achaia, Argolis, Arcadia, Laconia, Crete. In ruins, hedges, along streets and along alpine roads. Frequent. July–September. Perennial.

*27. *Urtica urens* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Cyclades, Crete, Peloponnesus. Widespread. In ruins of low areas. February–July. Annual.

9. Polygonaceae

*28. *Polygonum aviculare* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Cyclades, Crete and all over Greece. Cultivated fields, in ruins, and along streets of lowland and mountain regions. Annual.

*29. *Polygonum hydropiper* L. Thrace, Macedonia, Thessaly, Attica. Moist grounds. Frequent. July–September. Annual.

*30. *Polygonum persicaria* L. Thrace, Macedonia, Thessaly, Attica, Ionian Islands. Poorly drained areas. Rare. July–September. Annual.

*31. *Rumex acetosa* L. Thrace, Macedonia, Thessaly, Attica, Crete, Aetolia, Peloponnesus. In mountain and subalpine meadows. Frequent. May–July. Perennial.

*32. *Rumex acetosella* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Cyclades and other areas. On alpine hills, abandoned fields and rocky areas. Frequent. May–July. Perennial.

33. *Rumex crispus* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Euboea, Peloponnesus. In ruins, meadows and hedges of lowland and mountain regions. Rare. July–August. Perennial.

10. Chenopodiaceae

34. *Chenopodium ambrosioides* L. Attica, Aetolia, Laconia, Ionian Islands, Crete. Rocky fields, olive groves, and fields of lowland and mountain regions. Rare. June–August. Annual.

11. Caryophyllaceae

*35. *Agrostemma githago* L. Thrace, Macedonia, Thessaly, Attica, Ionian Islands, Crete, Euboea, Argolis, Messeni. In cornfields and cultivated areas. Frequent. April–June. Annual.

*36. *Saponaria officinalis* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Cyclades, Euboea, Argolis, Boeotia, Aetolia, Laconia (along the Eurotas River). Sandy grounds, orchards of lowland and mountain regions. Rare. June–September. Perennial.

37. *Saponaria vaccaria* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Cyclades, Crete, Argolis. Cultivated fields and cornfields. Rare. May–July. Perennial.

12. Ranunculaceae

*38. *Aconitum napellus* L. Laconia. Very rare. July–August. Perennial.

39. *Actaea spicata* L. Macedonia, Attica, Mountains of Laconia. Woods

FIG. 2 (*Left*). *Hyoscyamus albus* L., growing along a rock outeropping in Salonika.

FIG. 3 (*Right*). Professor Lavrentiades of the University of Salonika, co-author in the preparation of this article.

of mountains. Very rare. June–July. Perennial.

*40. *Adonis aestivalis* L. Thrace, Eperus, Ionian Islands, Crete, Attica, Arcadia, Messeni, Argolis, Boeotia. In grain fields of plains regions. Widespread. April–June. Annual.

*41. *Adonis autumnalis* L. Thrace, Eperus, Ionian Islands, Crete, Attica, Euboea, Peloponnesus. Frequent. April–June. Annual.

*42. *Adonis flammea* Jacq. Thrace, Macedonia, Attica, Eperus, Arcadia, on Mt. Parnassus. Cultivated fields. Rare. April–June. Annual.

43. *Adonis pyrenaica* DC. Rocky places of lower regions of Mt. Kyllene. Very rare. April–May. Perennial.

*44. *Anemone coronaria* L. Macedonia, Ionian Islands, Cyclades, Crete, Peloponnesus, Most of Greek islands. Widespread. January–March. Perennial.

45. *Anemone hortensis* L. Macedonia, Attica, Thessaly, Ionian Islands, Messeni. In hedges, on rocky hills. Rare. Perennial.

46. *Anemone nemarosa* L. Macedonia, Attica, on Mt. Parnassus. In dense woods, and shaded spots. Rare. April–May. Perennial.

47. *Anemone palmata* L. Corfu, Messeni. Very rare. February–May. Perennial.

48. *Caltha palustris* Bois. In humid subalpine regions of Mt. Ghavelli,

Zygos, Tragopetra, Pindos Mts., Aetolia. Rare. April–May. Perennial.

49. *Ceratocephalus falcatus* L. Macedonia, Thessaly, Attica, Argolis, Arcadia, Achaia. Sandy grainfields, and cultivated fields. Frequent. February–April. Annual.

50. *Clematis flammula* L. Thrace, Macedonia, Thessaly, Eperus, Attica, Cephalonia, Corfu, Zante, Elis, Laconia, Doris. On shrubs. Frequent. May–July. Perennial.

51. *Clematis recta* L. Achaia, Argolis, Cephalonia. Shrubs on hills. Very rare. June–July. Perennial.

*52. *Clematis vitalba* L. Thrace, Macedonia, Attica, Eperus, Thessaly, Achaia, Euboea, Aegean Islands, Ionian Islands, Melos Isle. On hedges and woods. Frequent. May–July. Perennial.

53. *Delphinium ajacis* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Phocis, Argolis, Laconia, Arcadia, Achaia. Dry ground of lower and mountainous regions up to 4000 ft. above sea level. Frequent. April–July. Annual.

54. *Delphinium consolida* L. Thessaly, Eperus, Sporades Islands, near Lamia, Thebes, Levadia. Uncultivated fields. Rare. June–July. Annual.

*55. *Delphinium peregrinum* L. Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Cyclades, Crete, Messeni, Strophades Islands, Cythera Island. Frequent. Annual.

56. *Delphinium staphisagria* L. Thessaly, Ionian Islands, Cyclades, Crete, Euboea, Peloponnesus. Ruins and hedges. Frequent. April–May. Annual.

*57. *Helleborus cyclophyllus* Boiss. Macedonia, Eperus, Thessaly, Ionian Islands, Euboea, Skiathos Island, Boeotia, Achaia. Mountain woods up to 6500 feet above sea level. Frequent. February–March (on the mountains till June). Perennial.

*58. *Helleborus niger* L. On Mts. Oeta, Korax, Parnassus, Tymphrestus and Dirphys; Cephalonia Isle and Laconia. In woods. Rare. January–March. Perennial.

*59. *Nigella arvensis* (b. glauca) Bois. Thrace, Macedonia, Eperus, Thessaly, Attica. Cultivated flat lands. Frequent. June–August. Annual.

60. *Nigella damascena* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Cyclades, Crete, Peloponnesus, Aiyina Island, Syria Island, Euboea, and in Pharmacuses Islands. Cultivated flat lands. Frequent. June–August. Annual.

61. *Nigella sativa* (b. cretica) D.C. Crete. Humid areas. Very rare. May–July. Annual.

62. *Paeonia corallina* Retz. Macedonia, Attica, Euboea, Laconia, Crete, Mountains. Very rare. April. Perennial.

63. *Paeonia officinalis* L. Macedonia, Attica, Eperus. Associated with species of the genus "Rubus". Rare. May–June. Perennial.

*64. *Ranunculus arvensis* L. Thrace, Macedonia, Thessaly, Attica, Crete, Ionian Islands, Argolis, Aiyina, Arcadia, Laconia, Messeni. Cultivated areas. Frequent. April–May. Annual.

*65. *Ranunculus flabellatus* Desf. Thrace, Ionian Islands, Cyclades, Crete, Attica, Aiyina; Poros, Syra, and Tenos Isles, Laconia, Messeni. Hills of lower and mountain regions. Frequent. March–May. Perennial.

66. *Ranunculus flammula* L. Thrace, Peloponnesus. Streams. Rare. May–August. Perennial.

67. *Ranunculus lingua* L. Macedonia, Attica, Peloponnesus, Methone, Messeni, Chimova, Kardamyli, Argos. Marshes. Rare. June–July. Perennial.

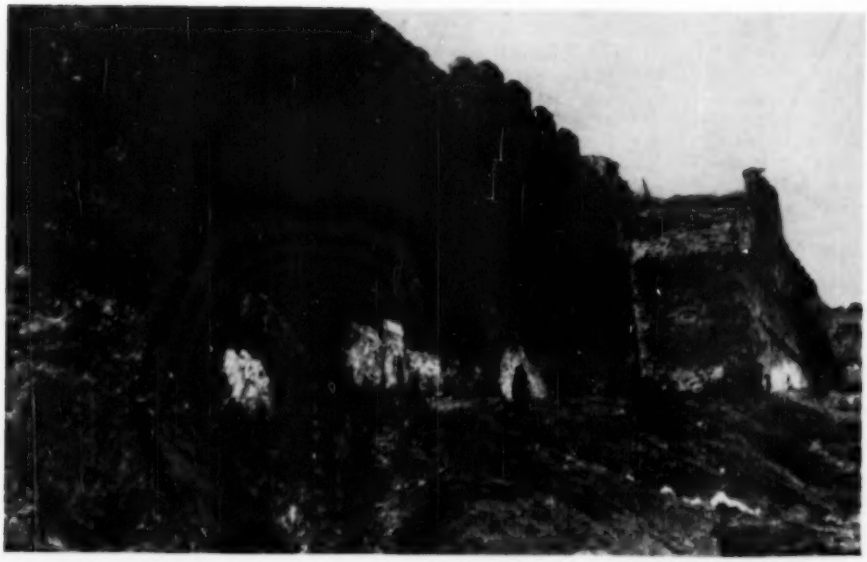
*68. *Ranunculus muricatus* L. Thrace, Macedonia, Thessaly, Attica, Ionian Islands, Cyclades, Crete, Corinth Isthmus, Argolis, Aiyina. Humid areas and ditches. Widespread. March–May. Annual.

69. *Ranunculus parviflorus* L. Achaia, Peloponnesus. Cultivated areas. Very rare. March–May. Annual.

*70. *Ranunculus repens* L. Macedonia, Thessaly, Attica, Achaia, Pindos Mountains. In marshes and ditches. Rare. May–June. Perennial.

*71. *Ranunculus sardous* Crantz. Thrace, Macedonia, Thessaly, Attica, Eperus, Crete, Ionian Islands, Peloponnesus, Sporades Islands. Poorly drained areas and marshes. Widespread. March–June. Annual.

*72. *Ranunculus sceleratus* L. Thrace, Macedonia, Thessaly (on Mt. Pelion and around the town of Volos). In ditches and marshes. Very rare. May–September. Annual.



FIGS. 4 and 5. Parts of the ancient wall around the old city of Salonika where many poisonous plants were collected.

*73. *Ranunculus trichophyllus* Chaix. Thrace, Macedonia, Thessaly, Attica, Aetolia, Skopelos Island, Crete, Ionian Islands. Stagnant water and sluggish streams. Frequent. May–July. Perennial.

74. *Ranunculus trilobus* Desf. Damp places. Very rare. April–August. Annual.

75. *Ranunculus tripartitus* D.C. Cyclades Islands, Melos Island. Aquatic. Rare. March–April. Perennial.

76. *Ranunculus velutinus* Ren. Macedonia, Thessaly, Attica, Crete, Ionian Islands, Boetia, Aetolia, Peloponnesus. Moist meadows. Rare. April–May. Perennial.

77. *Thalictrum aquilegifolium* L. Thrace, Macedonia, Thessaly, Attica, Laconia, Pindos Mountains. In subalpine woods. Rare. May–July. Perennial.

13. Papaveraceae

*78. *Chelidonium majus* L. Thrace, Macedonia, Eperus, Attica, Aetolia, Mt. Korax, Mountains. Widespread. May–June. Annual.

*79. *Glaucium luteum* Scop. Thrace, Macedonia, Eperus, Attica, Ionian Islands, Cyclades, Crete. Sandy areas near seashore. Frequent. May–June. Annual.

*80. *Hypecoum pendulum* L. Thrace, Macedonia, Attica. On plains and cultivated fields. Rare. April–May. Annual.

*81. *Hypecoum procumbens* L. Thrace, Macedonia, Cyclades, Crete, Attica, Aiyina, Laconia, Corfu. Sandy soils and seashores. Frequent. March–May. Annual.

82. *Papaver argemone* L. Thrace, Attica, Ionian Islands, Cyclades, Crete, Argolis. Cultivated fields and dry hills. Rare. April–May. Annual.

83. *Papaver dubium* L. Thessaly, Argolis, Laconia, Messeni. Uncultivated areas. Rare. April–July. Annual.

*84. *Papaver hybridum* L. Thrace, Macedonia, Thessaly, Eperus, Crete, Attica, Laconia, Achaia, Skopelos Island. On cultivated slopes and hills. Very frequent. March–April. Annual.

*85. *Papaver rhoeas* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Cyclades, Crete. Widespread. May–July. Annual.

*86. *Papaver somniferum* L. Thrace, Cyclades, Crete. Cultivated for its economic and ornamental importance. Annual.

87. *Roemeria hybrida* D.C. Thrace, Macedonia, Thessaly, Attica, Crete, Euboea, Aiyina, Corinth, Argolis, Laconia, Syra, Tenos. Cultivated fields. Frequent. April–May. Annual.

14. Cruciferae

88. *Brassica arvensis* L. Cephalonia, Palike. Damp cultivated areas. Rare. April–June. Biennial.

89. *Camelina microcarpa* Andrz. Macedonia, Attica, Aiyina. Cultivated fields. Very rare. March–April. Annual.

*90. *Raphanus raphanistrum* L. Thrace, Macedonia, Thessaly, Attica, Ionian Islands, Cyclades, Crete, Argolis. Cultivated fields. Frequent. March–May. Annual.

91. *Sisymbrium altissimum* L. Thrace, Macedonia, Thessaly. At the bottoms of mountains. Very rare. April–May. Biennial.

15. Rosaceae

*92. *Prunus amygdalus* Batsch. Eperus, Thessaly, Ionian Islands, Cyclades, Crete. In hedges and woods. Frequent. January–March. Perennial.

*93. *Prunus armeniaca* L. Cultivated plant. Widespread. Perennial.

*94. *Potentilla recta* L. Macedonia, Thessaly, Boeotia, Laconis, on Mt. Saint Pascha of Pindos Range. In grass fields. Rare. May–July. Perennial.

*95. *Prunus spinosa* L. Thrace, Macedonia, Thessaly, Attica, Ionian Islands, Attica, Elis, Laconia. Shrubby places of lowland and mountain regions. Frequent. March–April. Perennial.

16. Cucurbitaceae

*96. *Bryonia dioica* Jacq. Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Cyclades, Aetolia, Peloponnesus, Poros, Syra Island, Chios. In hedges and shrubby places of lowland and mountain regions. Frequent. April–May. Perennial.

*97. *Ecballium elaterium* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Cyclades, Crete, Peloponnesus. Ruins and uncultivated fields of plains regions. Widespread. May–September. Perennial.

FIG. 6 (*Upper*). *Melia azedarach*, the China Tree, growing on the campus of an agricultural school outside Salonika.

FIG. 7 (*Lower*). Professor O. Anderson of the Dairy Department, Connecticut State University, Dairy Advisor, M.S.A., Paris, examining a flowering branch of *M. azedarach*.

17. Crassulaceae

*98. *Sedum acre* L. Thrace, Macedonia, Eperus, Thessaly, Crete, Peloponnesus, Cephalonia, Pindos Mountains, Peleon Mountain, Mt. Olympus, Aetolia, Achaia, Laconia. On rocky places of mountain and alpine regions. Widespread. June–August. Perennial.

*99. *Sedum amplexicaule* D.C. Thrace, Macedonia, Thessaly, Cyclades, Phocis, Attica, Argolis, Poros, Laconia, Messeni. On rocky slopes of plain and mountain regions. Frequent. June–July. Perennial.

18. Leguminosae

100. *Anagyris foetida* L. Thrace, Macedonia, Thessaly, Attica, Ionian Islands, Cyclades, Crete, Euboea, Argolis, Messeni, Aiyina, Syra Isle. Among bushes and olive-trees, on open hills. Frequent. January–March. Perennial.

101. *Coronilla glauca* L. Macedonia, Attica, Ionian Islands, Euboea, Boeotia, Aetolia, Messeni. On steep slopes of plain and submountain regions. Rare. April–May. Perennial.

*102. *Coronilla varia* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Crete, Aetolia, Achaia, Argolis. Dry areas and among shrubs of plains and mountain regions. Frequent. May–July. Perennial.

*103. *Lathyrus aphaca* L. Thrace, Macedonia, Eperus, Thessaly, Ionian Islands, Cyclades, Attica, Crete, Boeotia, Argolis, Arcadia, Elis, Syra, Skopelos. Semi-arid, cultivated grounds of plain and submountain regions. Widespread. March–May. Annual.

*104. *Lupinus angustifolius* L. Thrace, Macedonia, Thessaly, Cyclades, Crete, Attica, Euboea, Achaia, Argolis, Laconia. Cultivated fields and sandy places. Frequent. March–May. Annual.

*105. *Melilotus alba* Desr. Thessaly, Eperus, Attica, Arcadia. In ruins and sandy ground. Frequent. May–August. Biennial.

*106. *Robinia Pseudacacia* L. Cultivated ornamental plant. Perennial.

*107. *Spartium junceum* L. Thrace, Macedonia, Eperus, Thessaly, Ionian Islands, Cyclades, Crete, Aegean Islands, Chios, Naxos, Potos. Mountain regions.

*108. *Trifolium arvense* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Cyclades, Crete, Euboea, Acarnania, Achaia, Messeni, Laconia, Argolis, Sporades. On shrubby and rocky places of mountain regions. Widespread. May–July. Annual.

*109. *Trifolium hybridum* L. Peloponnesus, Argolis, Messeni, Zante. Meadows and woods of submountain to alpine regions. Rare. June–August. Perennial.

*110. *Trifolium incarnatum* L. Messeni, Cephalonia. Lowlands. Rare. April–May. Annual.

111. *Ulex europaeus* L. Around Kalamata and Messeni. Very rare. Perennial.

19. Linaceae

*112. *Linum usitatissimum* L. Thrace, Macedonia, Crete. Cultivated for its economic use. April–June. Annual.

20. Zygophyllaceae

*113. *Tribulus terrestris* L. Thrace, Macedonia, Attica, Thessaly, Eperus, Ionian Islands, Cyclades, Crete, Euboea. Plains, sandy areas and along streets. Widespread. May–October. Annual.

21. Rutaceae

*114. *Peganum harmala* L. Thrace, Macedonia, Thessaly, Attica, Corinth, Peloponnesus, Cyclades, Crete. In ruins and crop fields. Rare. May–July. Perennial.

*115. *Ruta graveolens* L. Thrace, Macedonia, Thessaly, Sporades, Islands, Euboea, Attica, Corinth, Argolis, Laconia, Aegean Islands, Eperus, Ionian Islands. Rocky hills. Frequent. May–June. Perennial.

22. Meliaceae

*116. *Melia azedarach* L. Ornamental tree. Frequent on the edges of roads. Perennial.

23. Euphorbiaceae

*117. *Euphorbia cyparissias* L. Macedonia, Attica. Very rare. April–June. Perennial.

*118. *Euphorbia helioscopia* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Cyclades, Crete, and all over Greece. Cultivated fields,

rocky areas, ruins. Widespread. February–July. Annual.

119. *Euphorbia lathyris* L. Macedonia, Laconia. In fields and poorly drained areas. Rare. June–July. Annual.

*120. *Euphorbia peplus* L. Thrace, Macedonia, Ionian Islands, Cyclades, Crete, Attica, Peloponnesus, Aegean Islands. Cultivated areas of lowland regions. Widespread. March–October. Annual.

*121. *Mercurialis annua* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Cyclades, Crete, and generally all over Greece. Cultivated areas, ruins and vineyards. Frequent. June–July. Annual.

FIG. 8. Peasant women hand-weeding a vegetable garden. The men are conspicuous by their absence. Eradication of poisonous plants would, of necessity, have to follow the same pattern.

*122. *Mercurialis perennis* L. Thrace, Macedonia, Phocis, Euboea. Woods of mountain regions. Very rare. March–May. Perennial.

123. *Ricinus communis* L. Cultivated, and in ruins of suburbs, Crete. Rare. April–May. Annual.

24. Buxaceae

*124. *Buxus sempervirens* L. Macedonia, Eperus, Thessaly, Attica, Euboea. In subalpine and alpine woods. Rare. March–June. Perennial.

25. Anacardiaceae

125. *Rhus coriaria* L. Thrace, Macedonia, Thessaly, Attica, Eurytania, Phthiotis, Achaia, Arcadia, Messeni, Laconia. Mountain regions. Rare. May–June. Perennial.

*126. *Rhus cotinus* L. Thrace, Macedonia, Thessaly, Eperus, Attica, Ionian Islands, Boeotia, Messeni, Laconia. Among bushes and woods of mountain regions. Frequent. May–June. Perennial.

26. Coriariaceae

127. *Coriaria myrtifolia* L. Peloponnesus. Humid areas. Rare. March–April. Perennial.

27. Hippocastanaceae

128. *Aesculus hippocastanum* L. Eperus, Thessaly, Phthiotis, Eurytania, Crete. In mountain woods. Rare. May–June. Perennial.

28. Rhamnaceae

129. *Rhamnus cathartica* L. Macedonia, Attica, Ionian Islands, Laconia. Very rare. May–June. Perennial.

29. Hypericaceae

*130. *Hypericum crispum* L. Thrace, Macedonia, Thessaly, Ionian Islands, Cyclades, Crete, Attica, Achaia, Argolis, Laconia. On plains, fields, uncultivated fields and vineyards. Widespread. June–August. Perennial.

*131. *Hypericum perforatum* L. Thessaly, Eperus, Euboea, Attica, Arcadia, Crete, Aegean Islands, Ionian Islands, Zante, Cephalonia, Corfu. Plains, hills, hedges. Rare. June–July. Perennial.

30. Thymelacaceae

132. *Daphne cucorum* L. Attica. Steep mountains. Rare. Perennial.

133. *Daphne gnidium* L. Attica. Weedy areas of lowland regions. Perennial.

*134. *Daphne mezereum* L. Macedonia, Thessaly, Attica, Laconia. Woods. Rare. February–April. Perennial.

31. Araliaceae

*135. *Hedera helix* L. Thrace, Macedonia, Eperus, Thessaly, Ionian Islands, Crete, and all over Greece. On walls and trees. Widespread. October–November. Perennial.

32. Umbelliferae

*136. *Apium graveolens* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Argolis, Laconia, Sapienza Island, Chios, Paros, Kos, Syra, Tenos, Crete, Zante, Cephalonia. Annual.

137. *Cicuta virosa* L. Eperus, Lake Ionina. Very rare. July–August. Perennial.

*138. *Conium maculatum* L. Thrace, Macedonia, Thessaly, Attica, Ionian Islands, Crete, Phthiotis, Aetolia, Boeotia, Elis, Laconia. Rocky ground along streets, and in hedges of plain and mountain regions. Rare. June–July. Biennial.

*139. *Daucus carota* L. Thrace, Macedonia, Eperus, Thessaly, Ionian Islands, Cyclades, Crete, and all over Greece. Fields, hills, and along hedges of plains and mountainous regions. Frequent. Cultivated plant. April–September. Perennial.

140. *Helasciadium nodiflorum* Koch. Thrace, Macedonia, Thessaly, Attica, Aetolia, Poros, Cythnos, Messeni, Achaia, Zante, Leucas, Crete. In rivers, marshes, and swamps. Rare. April–July. Perennial.

141. *Oenanthe fistulosa* L. Thrace, Eperus, Thessaly, Attica, Ionian Islands, Arcadia. In marshes, wet meadows of plains and mountain regions. Rare. June–July. Perennial.

142. *Oenanthe phelladrium* Lam. Thrace, Macedonia, Thessaly, Attica, Eperus. In marshes, swamps and rivers. Rare. June–July. Perennial.

143. *Oenanthe pimpinelloides* L. Thrace, Macedonia, Thessaly, Attica, Ionian Islands, Cyclades, Crete, Acarnania, Aetolia, Euboea, Elis, Achaia, Arcadia, Messeni. Wet meadows and dry shrubby places of lowland and mountain regions. Rare. May–June. Perennial.

144. *Pastinaca sativa* L. Macedonia, Attica, Thessaly, Boeotia, Peloponnesus, Aegean Islands. Undergrowth in mountain regions. Very rare. July–September. Biennial.

*145. *Petroselinum sativum* Hoffm. Thrace, Macedonia, Thessaly, Crete, Euboea. Steep slopes of plains regions and as cultivated plant. Rare in wild state. June–July. Annual.

146. *Sium latifolium* L. Macedonia, around Levadia and Athens. Very rare. Perennial.

33. Primulaceae

*147. *Anagallis arvensis* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Cyclades, Crete. On sandy soils, cultivated fields of plains and mountain regions. Frequent. March–October. Annual.

34. Oleaceae

*148. *Ligustrum vulgare* L. Thrace, Macedonia, Thessaly, Attica, Euboea, Boeotia, Achaia, Arcadia, Corfu. Hedges and among shrubs of mountain regions. Rare. April–June. Perennial.

35. Apocynaceae

*149. *Nerium oleander* L. Macedonia, Thessaly, Attica, Ionian Islands, Cyclades, Crete, and Eperus. Slopes of ravines. Frequent. May–August. Perennial.

36. Asclepiadaceae

150. *Vincetoxicum nigrum* Moench. Thessaly, Aetolia. Subalpine. Rare. June–July. Perennial.

37. Convolvulaceae

*151. *Convolvulus arvensis* L. Thrace, Macedonia, Thessaly, Eperus, Ionian Islands, Cyclades, Crete. Cultivated fields, along streets, and on hedges of plains and mountain regions. Widespread. May–August. Perennial.

*152. *Convolvulus sepium* L. Thrace, Macedonia, Thessaly, Ionian Islands, Crete, Attica. Hedges and marshes. Frequent. May–September. Perennial.

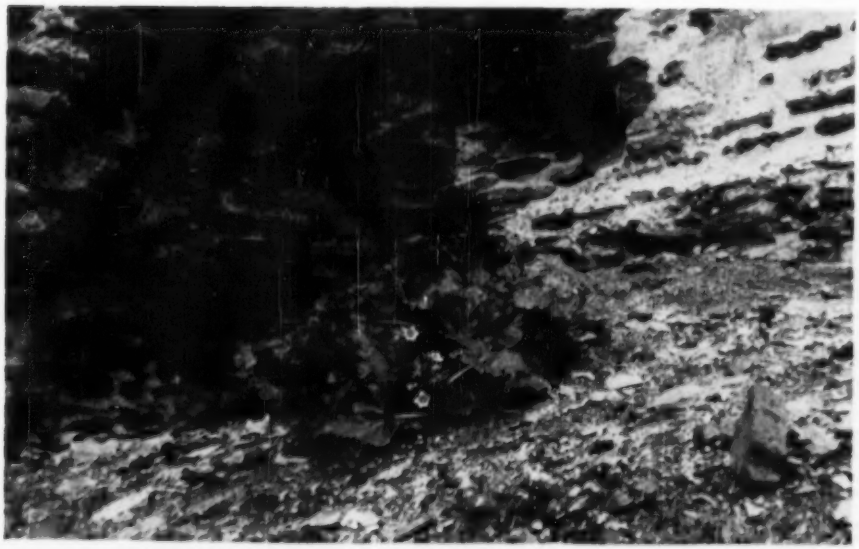


FIG. 9 (*Upper*). *Ecbalium elaterium* L., growing in the ruins of the old wall in Salonika.
FIG. 10 (*Lower*). *Peganum harmala* L., growing in someone's weedy backyard in Salonika.

38. Boraginaceae

*153. *Echium vulgare* L. Thrace, Macedonia, Thessaly, Ionian Islands, Attica, Laconia. Sandy cultivated areas and damp slopes of plains regions. Very rare. May–July. Biennial.

39. Labiatae

154. *Leonurus cardiaca* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Eurytania, and Achaia. Hills and ruins of plains and mountain regions. Rare. June–August. Perennial.

40. Solanaceae

*155. *Atropa belladona* L. Thrace, Macedonia, Attica, Thessaly. Shady places and mountain woods. Rare. June–July. Perennial.

156. *Datura metel* L. Laconia, in the Eurotas River. On the plains of Helos (town of Peloponnesus). Very rare. Annual.

*157. *Datura stramonium* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Crete, Aetolia, Arcadia, Messeni, Laconia. Cultivated places, in ruins of plains and submountain regions. Frequent in Eperus and Thessaly. June–September. Annual.

*158. *Hyoscyamus albus* L. Thrace, Macedonia, Thessaly, Attica, Ionian Islands, Cyclades, Crete, Messeni. Ruins, along roads, on walls, in plains regions. Rare. February–October. Annual and perennial.

*159. *Hyoscyamus niger* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Crete, Euboea, Laconia. Ruins and semi-arid areas of plains and mountain regions. Rare. April–July. Annual or biennial.

160. *Lycium barbarum* L. Thrace, Macedonia, Crete, around Athens, Tenos, Naxos. Hedges and roads. Rare. February–June. Perennial.

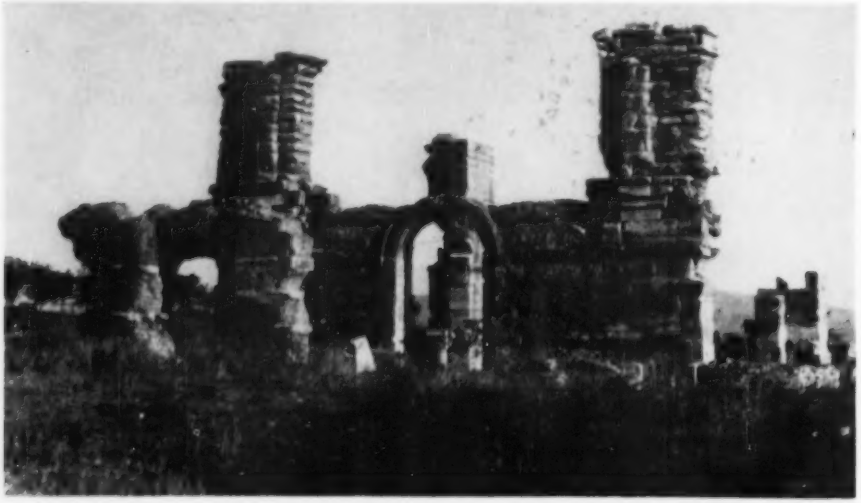


FIG. 11. The ruins of the ancient and historic city of Philippi offer a rich source of poisonous plants.

161. *Lycium europaeum* L. Thrace, Eperus, Thessaly, Ionian Islands, Athens, Laconia, Cythaera. Hedges and roads. Rare. February–June. Perennial.

162. *Nicotiana glauca* Grah. Cultivated as ornamental plant in Thrace, Cyclades, Crete. Perennial.

163. *Nicotiana rustica* L. Cultivated as ornamental plant. Annual.

164. *Nicotiana tabacum* L. Cultivated plant. Annual.

165. *Solanum dulcamara* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Cyclades, Euboea, Aetolia, Boeotia, Argolis, Achaia, Laconia. Wet

grounds, along banks of rivers, among trees of plains and mountain regions. Rare. May–August. Perennial.

*166. *Solanum nigrum* L. Thrace, Macedonia, Eperus, Thessaly, Ionian Islands, Cyclades, Crete. Sandy dry places all over Greece. Widespread. January–July. Annual.

*167. *Solanum pseudocapsicum* L. Attica, Cultivated as ornamental plant. Rare in wild state. Perennial.

*168. *Solanum sodomaeum* L. Around Thessalonika. Cultivated fields, along roads, in ruins. Very rare. Perennial.

*169. *Solanum tuberosum* L. Cultivated plant. Perennial.

41. Scrophulariaceae

*170. *Antirrhinum majus* L. Thrace, Attica, Ionian Islands, Cyclades, Laconia, Hydra, Argolis, Crete. Old walls and slopes of plains regions. Rare. March–September. Perennial.

171. *Antirrhinum orontium* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Cyclades, Crete, Aetolia, Poros, Sporades. Semi-arid hills, steep slopes, cultivated fields and vineyards of plains regions. Infrequent. March–June. Annual.

172. *Digitalis ambigua* Mutt. Macedonia. Eperus, Thessaly, Attica. In woods of mountain and subalpine regions. Rare. June–July. Perennial.

173. *Digitalis lutea* L. Arcadia. Woods. Very rare. June–July. Perennial.

174. *Gratiola officinalis* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Peloponnesus. Marshes and moist grounds. Very rare. June–August. Perennial.

*175. *Scrophularia camina* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Cyclades, Crete, Peloponnesus. Dry grounds, hills, stony fields. Widespread. March–July. Perennial.

176. *Scrophularia nodosa* L. Macedonia, Thessaly, Attica, Ionian Islands, Laconia. Moist woods. Rare. June–July. Perennial.

*177. *Scrophularia peregrina* L. Macedonia, Eperus, Attica, Ionian Islands, Cyclades, Crete, Aetolia, Peloponnesus. Ruins, along roads and on hedges of plains regions. Frequent. April–June. Annual.

*178. *Verbascum densiflorum* Bert. Thessaly, Cephalonia. Stony fields and barren areas of mountainous regions. Rare. May–July. Biennial.

*179. *Verbascum phlomoides* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Cyclades, Euboea, Argolis. Dry areas in mountainous regions. Frequent. May–August. Biennial.

*180. *Verbascum thapsus* L. Macedonia, Ionian Islands. Widely distributed. Well-drained rocky soils of plains regions. Frequent. May–July. Biennial.

42. Caprifoliaceae

181. *Sambucus racemosa* L. Arcadia. On hills. Very rare. April–May. Perennial.

43. Compositae

*182. *Echinops ritro* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Aetolia, Peloponnesus. Rocky mountain areas. Widespread. July–August. Perennial.

183. *Senecio jacobaea* L. Macedonia, Thessaly, Attica, Eperus. Mountains. Very rare. July–August. Biennial.

*184. *Senecio vulgaris* L. Thrace, Macedonia, Eperus, Thessaly, Attica, Ionian Islands, Cyclades, Crete. Widespread. Ruins and cultivated fields. Annual.

185. *Tanacetum vulgare* L. Macedonia, Thessaly, Attica, Ionian Islands. Among shrubs or in woods. Very rare. July–August. Perennial.

Bibliography

Bailey, L. H. Manual of cultivated plants. 1949.

Bonnier, Gaston. Flore complète de France, Suisse et Belgique. Tome I–XII.

———. Plantes medicinales, plantes mellifères, plantes utiles et nuisibles.

Fernald, M. L. Gray's Manual of Botany. VIII. 1949.

Food and Agricultural Organization of the United Nations, Report for Greece, 1947.

Halacsy, E. de. Conspectus Florae Graecae. Vols. I, II, III. 1904.

Hayek, A. Prodromus Florae Peninsulae Balcanicae. Vols. I, II, III. 1927.

Muenscher, Walter C. Poisonous plants of the United States. 1939.

A BOOK IN BRIEF

The Story of Spices[1]

JOHN W. PARRY

Editorial Note

As was stated in a review of this book (Economic Botany, July–September, 1954), every school child learns, presumably, that Columbus discovered America as a result of his effort to find a new route to the Indies, the lands of spices, but that the full significance of this statement, very likely, is appreciated by few. The importance lies in the fact that for two or three hundred years, beginning about five centuries ago, spices were of such great importance to the peoples of Europe that efforts to obtain them led to the greatest period of exploration the world has ever known, and to wars between nations contending for control of the routes to the sources of spices, once those sources had been found by the Europeans. Other groups of plants—food plants, drug plants and timber trees, to mention only three—have been of greater importance for the welfare of mankind, but none of them has had so great a world-wide influence on the political destinies of man as did spices. References to this role of spices are abundant in the popular literature on economically important plants, but nowhere else, at least in recent years, has the story been brought together and so admirably presented in delightful reading style as in this book. Excerpts, totaling 20 pages of the book, and abstracts of other parts constitute the following condensed version. So much more is contained in the book, however, that the student of ethnobotany, particularly of its historical aspects, will want to read the original in its entirety.

Spices in the Ancient World

"In the beginning, untouched and undisturbed save by the hand of God, the cumin and the anise of Egypt gave up their scent to the gentle Mediterranean breezes which cooled that arid land. In neighboring Asia, sweet marjoram grew and unknown monsoons brought rains to wet the cardamom and cinnamon of Malabar and Ceylon, while away in the volcanic islands of the Moluccas the fragrant cloves and nutmegs were fruiting on the mountain sides. How long it was before man, struggling through the mists of the primeval world, came to know and use these and all other aromatic plants, we cannot tell, but he must have gathered early the leaves, fruits, seeds, and roots of fragrant herbs common to his locality, and attributed to each a special virtue in his clouded scheme of things".

"And so . . . began the uses and customs which have endured through the ages—spices for food, spices for healing, and spices to placate the gods".

"Beyond these assumptions about the thoughts and practices of primitive man we cannot go. The stone implements and cave drawings tell us something about these early people and indicate the observing and inventive nature of their minds, but give us nothing on which to base the story of the spices in those very remote times. Not until after the passage of thousands of years did men develop a system of writing, and for the earliest records, we must go to the fertile valleys of the Euphrates, the Tigris, and the Nile".

There we find the ancient cultures of the Assyrians, the Babylonians and the Egyptians. According to translations of tablets now in the British Museum, the Assyrian gods drank a wine of sesame which thus is the earliest mentioned herb on record.

"Sesame was a source of food, wine, and oil, and its production was a mat-

[1] 208 pages. Chemical Publishing Company, Inc., 212 Fifth Ave., New York 10. 1953. $4.50.

ter for royal supervision and attention . . . this seed was often a subject of contract and accounting, as is shown by the references to sesame on tablets and deeds now in the Babylonian room of the British Museum. One of these covers a loan of silver and sesame seed; another records an allowance of food, drink, and sesame seed . . . ; and still another covers a loan of silver and sesame seed . . . . There is also a tablet of accounts concerning dates and sesame seed. All belong to the 6th century before Christ ".

" Throughout the years of Babylonian history, sesame seed was highly prized for its practical uses. It found favor for the making of sesame cakes, dainties, wine, and brandy. Sesame oil was used as a food, in medicine, and in the preparation of toilet requisites. Its skin-soothing properties made it most acceptable for oiling the body, and it was an excellent vehicle for perfumes. Herodotus, Greek historian (c. 484–425 B.C.), said it was the only oil used by the Babylonians. And Theophrastus, Greek scholar and famed plant student (c. 372–288 B.C.), commenting on sesame oil, said it was 'specially receptive' for the making of perfumes, and particularly rose perfume 'because of its viscid quality; and, when subjected to fire, it gives out a smell of sesame ".

" According to Herodotus, on one occasion sesame prevented the castration of a number of innocent boys. Periander, Tyrant of Corinth (665–585 B.C.), forcibly sent three hundred sons of noble Corcyraean families to Ayattes to become eunuchs. On their way to Sardis, their guards put in at Samos, and the Samians learning what was in store for the boys hurried them into the temple of Diana where they took sanctuary. Since the Corinthian guards could not enter the temple and take the boys, they stopped food supplies from reaching them. To prevent the boys being forced to surrender through hunger, a festival was originated by the Samians which called in part for choirs of youths and virgins to stand about the temple holding cakes of sesame in their hands which the unfortunate boys might snatch. The observance of the festival was kept going for so long a time that the Corinthian guards gave up their vigil and left the city, and then the Samians returned the boys to their parents in Corcyra ".

The Assyrians, a war-like people on both sides of the Tigris, established themselves about 3000 B.C., and among the 200 or so plants known to Assyrian doctors and chemists, the herbs cardamom, cumin, dill, fennel, origanum, thyme, saffron and sesame have been identified. And in the garden of one of the kings of Babylon, cardamom, coriander, dill, garlic, onion, thyme and saffron have been recorded.

" The aromatic plants were early employed in fumigation. It was natural that the sweet fragrance of the spices should have been associated with purity by the ancients. To them that which was foul-smelling would be a manifestation of evil, only to be combatted and overcome by the clean sweetness of the aromatics, and so, for cleansing purposes, the spices found great favor in the eyes of the priests. An early example of this might be that of Gudea, Patesi of Lagash (c. 2450 B.C.), who, in preparation for the building of a temple, purified the city by special rites and kindled a fire of aromatic woods to make a sweet savor for the gods. And it is probable that this was the beginning of the practice of using spices to fumigate the streets of cities before royal visits, and to ward off disease in times of plague as was done in Europe during the Middle Ages ".

" Spice plants played a part in many of the incantations, magical rites, and ceremonies performed by the priests in

behalf of those plagued with sickness or suffering from spells and bewitchments. In the second tablet of the Maklu series of Assyrian incantations addressed chiefly to the Fire-god, the performance of the ritual was to be accompanied by the burning of the flower of sesame. In the fifth tablet, mint and cassia play a prominent part. In the sixth tablet of the Sharpu series, addressed to the god Marduk in behalf of a man whom a demon had plagued with sickness, the priest was to cast into the fire a pod of garlic, certain seeds, and other substances. In other series of incantations, sesame wine, pleasant odors, and oils were to be set before the gods if the suppliants were to gain absolution and purity. On the occasion of the illness of the Babylonian king Shamash-shum-ukin (668–648 B.C.), twelve sesame cakes were called for in the incantation for the hand-raising prayer to Sin, the moon-god. He recovered only to burn to death later in his own palace".

"In their way of life, the Babylonians were a people fond of magnificence. They consumed lots of spices, and the spice trade was a major and lucrative business in Babylon. To her markets, the spices made their way by boat and caravan from widely separated points, and the merchandising of spices and spice products in this ancient city was great enough to merit mention with her trade in gold, silver, and precious stones, in the 18th chapter of The Revelation of St. John the Divine".

"The Egyptians believed the spirit returned to the body of the deceased, and, as far back as the 4th millennium before Christ, the bodies of kings and other highly placed persons were preserved against decay after death by a system of mummification which, in time, became quite elaborate. The spices first used in the mummifying process may have been anise and cumin, and perhaps sweet marjoram. Later, when cinnamon and cassia found their way into Egypt, these two barks were among the chief embalming spices".

In describing one of the three methods of embalming, Herodotus tells us that the bodies of the deceased were filled with "the purest myrrh, cassia, and every other sort of spicery except frankincense". He "does not mention the use of cassia or other spices in his description of the second and third methods of embalming which might indicate the high cost of spices, particularly those which had to be imported, in early Egyptian times. Cinnamon and cassia are not native to Egypt, and these spices could only arrive in that country after long transport and repeated handling, which must have made them very costly".

"The ancient Egyptians, no less than their contemporaries in Mesopotamia, used the spices to make unguents, perfumes and holy oils. About 2500 B.C., Pharaoh Sankhkere sent ships to the land of Punt, which seems to have been the regions on both sides of the Lower Red Sea and the Gulf of Aden, and in 1500 B.C., the Egyptian queen, Hatshepsut, sent an expedition of five ships down the Red Sea to this land for aromatics. According to her records, the ships took on board a goodly cargo of 'fragrant woods of God's land, heaps of myrrh-resin, of fresh myrrh trees . . . cinnamon-wood, with incense, eye-cosmetic . . .'. All these fragrant substances were necessary in their way of life and for their rites and ceremonies. The dead were anointed with holy oils, and scented unguents had their place in Egyptian funeral ritual".

Among numerous other references to the use of spices in the ancient world, Herodotus recorded that during the 20 years required to put together the 2,300,000 blocks of stone in the Great Pyramid of Gizeh, the 100,000 men who labored constantly on the project, and

were relieved every three months by a fresh lot, lived on a diet made up largely of garlic and onions in addition to radishes. And the Medical Papyrus of Thebes, written in 1552 B.C. and discovered by a German Egyptologist the latter half of the last century, lists several hundred remedies, among the identified plants of which are the names of coriander, caraway, sesame and saffron.

The ancient cities of Thebes, Memphis and Coptus for a long time were important as marketing and distributing centers for these spices. Eventually they were succeeded by the great city of Alexandria which became the leading emporium for trade in Oriental spices. It retained that position until the ascendency of the Portuguese in the 16th century A.D.

Spices in the Holy Bible

In the Holy Bible spices are mentioned in numerous places, especially in the Old Testament, both specifically and in general terms, beginning in the Book of Genesis, chapter 37, with the spice merchants who bought Joseph from his brothers in the year 1729 B.C. The final mention is in the 18th chapter of The Revelation of St. John the Divine where the fall of the great city of Babylon is foretold with its concomitant cessation of trade in "cinnamon, and odours, and ointments". Between these first and last allusions are others to balm, myrrh, coriander, sweet calamus, stacte, onycha, galbanum, frankincense, cumin, mint, anise, cassia and cinnamon. A great part of Solomon's wealth was derived from "the traffick of the spice merchants", and wealthy King Hezekiah of Judea owed much of his riches to "silver, gold, precious stones, and spices". These various spices were employed to make food more palatable and in the preparation of perfumed ointments and oils for religious ceremonies. Of them all, cassia and cinnamon were held in highest esteem by the Egyptians and Hebrews.

Cassia and Cinnamon in the Ancient Middle East

"Cinnamon formed part of the aromatics used by the Egyptian queen, Hatshepsut, some 3,500 years ago, and . . . cassia was employed in ancient Egypt to embalm the dead . . . cassia and cinnamon were ingredients of the holy annointing oils and perfumes used in the ritual of the tabernacle erected by Moses in the wilderness of Sinai . . . cassia was in the market of ancient Tyre, and . . . cinamon was an item of merchandise in the old and magnificent city of Babylon".

But cassia and cinnamon did not grow in Egypt or in the land of the Hebrews. The first is native to China and the East Indies; the second to Ceylon and the nearby Malabar coast of India. How, and by which people, then, did these fragrant spice barks first reach the Middle East? Some may have come to the Egyptians and Hebrews by overland caravans, but such journeys of thousands of miles over mountain ranges and across inhospitable deserts, through what today are India, Pakistan, Nepal, Afghanistan and Iran, renders it more likely that they were transported by some seafaring nation, especially those spices which came from the Molluccas of the East Indies. The only peoples who could have engaged in such extensive maritime commerce were the Arabs and the Phoenicians, and when the activities and history of both these nations are considered, the evidence is in favor of the former.

"In short: The Phoenicians were indeed notable manufacturers and great traders, but they produced no aromatics of their own and dealt in spices only as they dealt in every other kind of merchandise moving between East and West. They were renowned sailors and un-

doubtedly made long voyages to eastern parts of the world in later centuries, but nowhere in their maritime history are they mentioned as importers of cassia and cinnamon. Fundamentally, the Phoenicians were not spice merchants, but general merchants".

"The South Arabians traded in aromatics from earliest times; other merchandise they also handled, of course, but spice trading was their mainstay. They were sagacious merchants, and long acquainted with sea trade".

"It was to Southwest Arabia and the neighboring coastal land of Africa that Egyptians came for aromatics some 4,500 years ago; it was Arabian merchants who carried spicery from Gilead to Egypt some 3,666 years ago, and it was from Arabia that the ships of Hatshepsut sailed with cinnamon to Egypt some 3,500 years ago".

"The South Arabians depended on the aromatic trade almost entirely for a livelihood. They traded their fragrant gums and resins in the Red Sea and in the Persian Gulf, and it is to be expected that they ventured on voyages of exploration in search of new spices to meet the growing demand in the Middle East for aromatics. We cannot point to them having made long coastal voyages to the East in very early times anymore than we could to the Phoenicians, but we can clearly see why they, rather than the Phoenicians, should have made such voyages. The cinnamon which was employed by the Egyptian queen, Hatshepsut, in 1500 B.C., and the cassia and cinnamon which the Israelites used in the rites of the tabernacle in 1490 B.C., all had to come from spice lands farther east, and it is only reasonable to conclude that these fragrant barks came into the Middle East by way of a spice-dealing people; and no people in all the Middle East excelled the Arabians as spice merchants".

"The whole coastal region of Arabia from the Persian Gulf through Hadramaut to the Red Sea knew the traffic of the Arabian spice merchants. From her most ancient people, through the Minaeans and Sabaeans to the Himyarites, the aromatic trade of South Arabia endured. The Sabaeans sent their ships overseas for spices and, for centuries, these people successfully monopolized the trade in cassia and cinnamon between eastern spice lands and the Middle East. They cleverly concealed the true source of cassia and cinnamon, and traded these fragrant spice barks to great advantage in all the markets of the Middle East".

"In conclusion: Spices were indivisible from the lives of the South Arabians; they were their heritage and their mainstay. South Arabians were traders and sailors from earliest times and, by necessity, must have sought new sources of spices to meet the great demand of Middle East peoples. Cinnamon was early associated with their name, and cassia and cinnamon were imported and distributed exclusively by them for centuries. There can be no doubt that they were the founders of the trade with Eastern spice lands which brought the first cassia and cinnamon to the Middle East".

"So, through a chain of traders, the cassia of Cochin-China probably made its way to Southern India, or the island of Ceylon, from where it was conveyed, together with the Malabar cinnamon, in Arabian vessels to the Persian Gulf. Some cassia and cinnamon must have been landed at Oman and from there transported by camel train to Arabia Felix for the trade with Egyptians and Hebrews and some was carried to the head of the Gulf for transportation into Babylonia and Assyria by way of the Tigris and Euphrates rivers".

The Arabian Spice Trade

"South Arabia became the great spice emporium of the ancient world, and South Arabians, the clever, mystifying

masters of a very lucrative trade in domestic and imported spices. It was not their intention to let outsiders learn too much about their activities, and to hide their trade secrets, they invented and spread some very fantastic tales, particularly in regard to the origin and production of the highly desirable and costly spice barks, cassia and cinnamon". These weird accounts have been handed down to us by Herodotus, Theophrastus and Strabo, and appear to have been accepted by them. They held that the spices were produced in Arabia, an idea that prevailed until attacked by the Roman naturalist Pliny the Elder who claimed that 'Arabia produces neither cinnamon nor cassia' and then recorded and blasted the ancient myths. Pliny was wise to the wily Arabian spice merchants and knew that they had been bluffing all along; that they did not produce cassia and cinnamon in their country; and that for centuries they had told ridiculous stories in order to keep up the price of their barks. Erudite as he was, however, Pliny did no more than substitute one fallacy for another, for he claimed that "cinnamon grows in the country of the Ethiopians . . . cassia grows not far from the plains where cinnamon is produced"!

"Pliny also mentions ginger and cardamom as products of Arabia, and apparently he had heard that some cardamom grew in India, but actually he had no more idea of the true origin of these spices than he had of cassia and cinnamon. We can be sure that the Arabians imported ginger and cardamom together with cassia and cinnamon, and that all these spices were part of their great and wisely protected trade in overseas aromatics. Considering the nature of all four products, it is understandable why they traded in them to the probable exclusion of pepper, which they left to others. Pepper had little to recommend itself to the people of those days, if we judge by the disparaging remarks of Pliny which we shall read later, whereas the others had a desirable fragrance particularly suited to the nature and customs of the people of the Middle East".

"Pliny contemptuously dismissed Arabia as the land of spices, but, nevertheless, Arabia was, in his day and had been for centuries before him, the spice emporium of the ancient world. Its trade was immense, lucrative, and well organized. The Arabs were astute and competent, and the hold they had gained on the spice trade before the days of Herodotus, they maintained long after the days of Pliny".

Uses of Spices in the Ancient Greek and Roman World

"In war and peace, palace and hovel, temple and arena, fact and fable, the spices had their part in the lives of the people of the ancient Greek and Roman world. In preparation for the passage of the Persian armies, soldiers burned all kinds of spices on the bridges built by Xerxes across the Hellespont, during his war against the Greeks in the 5th century before Christ. The soldiers of Alexander the Great, marching through Gedrosia from India, used spice plants for tent coverings and bedding. Laurel leaves decorated the weapons of Roman soldiers and adorned their fasces; and in them, Roman generals wrapped their dispatches. In the social life of the ancient Greeks and Romans, spices were the essence of personal luxury; and an important part of public functions, banquets and parties. Cardamom, cassia, cinnamon, and sweet marjoram were among the ingredients of their perfumes; and anise, basil, fennel leaves, coriander, and garlic were among their aphrodisiacs. Spice-scented oils to soothe the skin were a part of the routine of the bath, and used by athletes to anoint the body. Their wines were flavored with spices, and among their kitchen implements, they had mortars

and pestles in which to pound and powder the spices they used in cooking. Laurel leaves formed the wreaths with which the victors in the sacred games were crowned. Costly spices were among the most desirable of gifts, just as they had been in the days of Sheba and Solomon; cassia and cinnamon, for example, formed part of the royal gift presented by Seleucus I to the temple of Apollo at Miletus. Spices, and oils perfumed with spices, were placed in the temples for the acceptance of the gods. Spices were an important source of revenue for the royal coffers, and in the time of the early Ptolemies, their import was under royal control, as was also the manufacture of scented preparations from them, and the extraction of sesame oil. In medicine, the spices were used to heal the sick and the wounded; and they were employed lavishly in the funeral rites of prominent people".

"Most of the spices used by the people of today were known to the ancient Greeks and Romans. Anise was used in the kitchen for the making of seasonings, relishes and sauces, and together with cumin in the making of a cake which was customarily eaten by the Romans at the end of a meal to prevent indigestion. They considered aniseed excellent for flavoring wine. It was used to sweeten the breath, promote the appetite, as an aphrodisiac, and also as a moth repellent. In Pliny's day, the most esteemed anise was that of Crete, with Egypt supplying the next best in quality. Sweet basil was probably used for culinary purposes in those days, but all we know for sure is that it was used as an aphrodisiac, 'for which reason', says Pliny, 'it is given to horses and asses at the season for covering'. Caraway was principally employed for culinary purposes. Cumin found favor as a food seasoning and, with coriander, it was employed for preserving meat. Fennel was extensively employed in seasonings and to flavor sauces made with vinegar. The leaves of fennel found favor as an aphrodisiac. Garlic was a popular food and seasoning. According to Pliny, it was a dish of 'high rank' to the rural population of Africa. Beaten up with coriander, and taken in pure white wine, it was also used as an aphrodisiac. Ginger was employed in the kitchen to flavor meat dishes and to season relishes and sauces. Mint was a favorite food seasoning, and was used to flavor meat sauces. It was added to milk to prevent its turning sour, and to keep it from curdling. Like aniseed, it was employed to flavor wine. Peppermint sprays decorated the banquet tables, and both Greeks and Romans crowned themselves with it at their feasts. Mustard was a condiment, used, it would seem, in much the same way as we employ it today. Thyme was employed to flavor cheese and liquor. It was also used for fumigating".

"Both black and white pepper were employed in the kitchens of the ancient Greeks and Romans. When pepper first came into use in those parts, we do not know, but Theophrastus spoke about two kinds of pepper some 400 years before the publication of Pliny's *Natural History*. Pliny distinguished between black and white pepper and observed that the black 'is of a more agreeable flavor; but the white pepper is of a milder quality'. He did not have a very high regard for this spice".

In the realm of superstition and medical application the ancients entertained some strange notions about spices, and attributed weird and specific properties to each kind of spice. "Many of the fantastic claims, made for the medicinal virtues of the spices in those days, endured through the centuries to find their way into the leechbooks and herbals of the Middle Ages, and some have endured until this day".

Spices in the Early Christian Era and Middle Ages

"In the closing centuries of the pre-Christian era, sea trade between the Middle East and India began to increase rapidly. We have seen that the Arabians enjoyed for centuries a monopoly of the trade in Eastern spices which had not terminated by the time of Pliny. They were able to keep secret the true source of cassia and cinnamon, but it is not likely that they were able to keep secret the long voyages they were making to the East. Their trade expeditions must have been known to the international traders of Alexandria, even if the nature of their cargo was not. And it is certain that these merchants were watching them very carefully, and making plans to get into the Eastern trade themselves. These plans seem to have matured during the reign of Ptolemy Philadelphus (285–246 B.C.). The ancient canal which connected the Nile with the Red Sea was reopened, permitting entry to the Arabian Sea of Ptolemaic ships and those of the merchants of Alexandria, and trade between Egypt and India began. By the time of Strabo, as we have seen, there were regular sailings of large fleets of ships from the Red Sea".

An important factor in the development of this trade was the discovery of the monsoons, and both Arabians and Egyptians very likely took advantage of these favorable winds in traveling between their homelands and India. Until the ascendency of the Portuguese in the 16th century the Arabians remained active and dominant in the spice trade, despite their loss of a monopoly in the trade after the Romans conquered Egypt in the century before Christ and took over the sea trade started by the Ptolemies.

"During the first three centuries of the Christian era, trade between the Roman empire and the east, particularly India, became quite extensive, both by land and water. The spices of India made their way by the Red Sea to Coptus, Memphis, and Alexandria; and from Alexandria, they were distributed to Greece and Italy. The Arabians were actively engaged in this spice trade, and cinnamon, ginger, and pepper filled the cargo holds of their vessels. The demand for spices was very great, and to the Romans they were an important source of revenue. At the Roman custom house at Alexandria, imported goods were scrutinized and taxed, and cassia and cinnamon were among those on which tribute was levied".

"By the end of the third century at the latest, the Arabians had developed direct sea trade with China, and, in addition to China's cassia, they were probably obtaining spices from Chinese merchants which had come from the East Indies. Envoys from Java were reaching the court of China during the Han Dynasty, 206 B.C. to A.D. 220, and it is most likely that as a result, trade was carried on at that time between the two countries. During the Han Dynasty, it was the practice for those addressing the Emperor to perfume the breath by holding cloves in the mouth, and the cloves had to come from the East Indies because they are not a product of China".

The great importance of spices to the peoples of Europe in the following centuries is especially well illustrated by the ransom extracted from Rome early in the fifth century when it was besieged by Alaric, king of the Goths. Part of the ransom was 3,000 pounds of pepper, showing that this pungent spice was not less valuable than gold or silver, and that large quantities of it must have been reaching Europe at that time. In the Middle Ages, when the merchants of Venice waxed wealthy from their trade in Oriental spices and other goods, there were recorded in ecclesiastical literature

various gists of cinnamon, cumin and pepper. And in the 12th century there was a Pepperers' Guild in London.

Spices in the Travels of Marco Polo

The great tale of travel which Marco Polo, as a prisoner of war between Venice and Genoa in 1298, related to a scribe contains numerous allusions to spices, some in general terms, others specifically to sesame-seed oil, ginger, cassia, clove and pepper. Most important of these was pepper, and in the city of Hangchow, Polo related that the daily amount of this one spice brought in was 43 loads, "each load being two hundred and forty three pounds, or a total of 10,449 pounds"! Similar trade was carried on at other points. Kublai Khan, the emperor, derived a handsome profit from this immense trade, "and the spice merchants made a most respectable profit despite cutoms, freight, and other charges which amounted to fifty per cent of the value of the pepper cargo".

"Of the spices noted on his voyage home from the Straits of Malacca, Marco Polo mentions cloves in the Nicobar Islands, oil of sesame in Ceylon, and an abundance of pepper, ginger, and cinnamon on the Malabar coast of India".

"It is a strange and interesting thing that Marco Polo does not mention cinnamon when speaking of Ceylon. The finest and most fragrant cinnamon, from *Cinnamomum zeylanicum*, is native to Ceylon, but, for some unknown reason, its presence on the island seems to have remained unnoticed until the late 13th century when it is mentioned in the work of an Egyptian historian. In fact, apart from Marco Polo's reference to sesame, he does not mention spices at all when describing this island, yet the spice trade of Ceylon had been noted by previous travelers".

"Marco Polo also tells us of the use of oil of sesame in Abyssinia; of the port of Aden, 'frequented by ships arriving from India with spices and drugs'; and of a city named Kalayati situated three hundred miles southwest of Hormuz, where many trading vessels arrive from India loaded with spices which they sell to great advantage".

Spices and Their Uses in the Late Middle Ages

"By the 13th century the East Indies were the scene of a thriving trade in spices. Java was the principal spice-trading island, and Javanese traders brought the cloves, nutmegs and mace from the islands of the Moluccа groups for distribution to the world. Numerous Chinese junks reached the coast of Borneo and, from there, traded among the clove and nutmeg islands. From Java, Arabian merchants sailed west with their ships laden with pepper, cloves, nutmegs, mace, cassia, and ginger, in addition to their spice trade with southern India; and Chinese merchantmen carried pepper, cloves, nutmegs and mace to the ports of China. The East Indies gradually eclipsed the Malabar coast of India as the most important source of costly spices, and both places attracted the princes and merchants of western Europe to bring, in the 15th and 16th centuries, the greatest and brightest age of discovery the world has ever known".

"China continued to export her cassia, of which large quantities grew in Kwangsi province and Cochin China, to the west. Her ginger probably went no farther than neighboring Burma and the eastern provinces of India. Burma was not a producer of spices, but a consumer of no small account, if we believe the contents of an ancient inscription which says that the 13th-century king Narathihapate ate three hundred dishes of curry daily".

"The consumption of spices was

steadily increasing in the west, and in the fairs of Europe and England, oriental spices were regularly obtainable. In 13th-century England, mace was four shillings and sevenpence per pound, ginger one shilling and sixpence, pepper one shilling, cassia tenpence, and cumin twopence. These were high prices in those days, but understandable when we consider the long and hazardous voyages and overland journeys from the East, and the number of hands through which the spices passed ".

" There is little mention of spices in the next century. In 14th-century England, spices were still exacted as tribute or taxed for certain purposes. For example, in the reign of Edward I, we find that anise was among the commodities taxed to raise the funds required to defray the expense of repairing London Bridge. A new guild of Pepperers was organized in London in 1345. The Pepperers were among the wealthiest of merchants, and one had to be a pepperer of Soper Lane or a spicer of Cheap, in good standing, to belong to the fraternity. Cinnamon, pepper, and other spices were conveyed to the warehouses of the spice merchants by street porters, whose charges were a matter of agreement between themselves and the Pepperers Guild. Cassia buds were mentioned in this century: they were sold in London at eight to thirteen shillings per pound. Pepper increased in price to two shillings per pound ".

" Most decidedly, the spices were beyond the poor folk of those days, but the situation could hardly have been otherwise. All Europe depended on the Orient for pungent and fragrant spices: cloves, nutmegs and mace came from the Moluccas; pepper from southern India and Java; cassia from China and the East Indies; cinnamon from Ceylon and Malabar; and ginger from Malabar and perhaps the East Indies. And because there was no Suez Canal and no known road to the Orient, except through the lands of the Middle East, Europeans could not trade directly with those places ".

" The Arabs practically monopolized this trade in eastern waters, and the merchants and bankers of Venice controlled the spice trade in the Mediterranean. After leaving the hands of the native producers, the spices passed through numerous dealers before they reached the markets of the Black Sea and the Eastern Mediterranean, and with each change of ownership came an addition to the cost ".

" The balance of trade was in favor of the Orient, and to pay for the spices of the East, Europe shipped her gold and silver through Venetian banks, making the already wealthy merchants of Venice wealthier and adding to the fortunes of the royal coffers of the Middle East. But the people of the West were learning. Merchants and bankers in western and northern Europe were growing slowly more powerful; shipyards were building better ships; inquiring minds were busy; and eager, searching eyes were scanning the maps of the geographers ".

Preservation of food in those days depended on salting, drying and smoking, all of which must have resulted in very insipid food, the unpleasant flavor of which could be alleviated only by use of spices. " In the peasant home, we would not find the costly spices of the East. But in the kitchens of the great, every chef had his own ideas of seasoning and flavoring and every master his favorite spice. They used small, fragrant sticks of cinnamon and the delightful little clove buds to garnish dishes; pepper, cloves, ginger, mace, and onions stuck with cloves were common ingredients of pottage; clear soups were strained through bunches of fragrant herbs; anise, mint, and parsley were among the spices held best for gravies, sauces,

and relishes; dill flavored their vegetables and, in the later centuries, was used for pickling cucumbers; caraway and cumin flavored their soups; cheese, bread, and cakes were used in the preparation of dainties; fennel and coriander seeds were sugared and eaten as confections; oil was expressed from nutmeg and mace to flavor a dainty butter; cassia, cinnamon, cloves, nutmeg, mace, ginger, anise, sweet marjoram, thyme, and savory were employed to flavor puddings, tarts, pastries, cakes, and conserves; and rosemary, nutmeg, cinnamon, fennel, coriander, anise, cloves, and ginger went into the preparation of their many kinds of beverages, wines, and liquors".

"Throughout the Middle Ages, the medicinal uses for the spices were not dissimilar from those of the ancients. The Anglo-Saxons turned to the herbs for most of their remedies, and in their leechbooks are found the names of many spices. In the *Herbarum Apuleii Platonici*, said to be a 5th century work, but published in the 10th century, we find mention of coriander, dill, fennel, mint, marjoram, parsley, and sage".

The therapeutic qualities attributed to spices in the leechbooks and herbals of the Middle Ages were fantastic, and the importance of spices toward the close of that period is carried down to us in at least three famous pre-Columbian books—The Canterbury Tales, the Decameron of Boccaccio and The Arabian Nights.

The Portuguese Seek the Spice Islands

"In the 15th century, the spice trade of the East and Middle East was dominated by Moslem merchants. Their Eastern pivotal points were Calicut, Colombo, and Malacca. In the Middle East, their greatest markets were Constantinople and Alexandria. Spices bound for Constantinople from India and the Far East went by way of the island of Hormuz in the Persian Gulf; those for Alexandria by way of the Red Sea and the ancient city of Mecca. In the Mediterranean, the Venetians were the undisputed masters of the spice traffic moving between Middle East centres and European points".

"The Middle Ages had witnessed the steady rise of Venice in commercial and maritime importance. From her favorable situation at the head of the Adriatic, between East and West, she had been of strategic importance in the affairs of many nations, and had fattened on the territorial and trading concessions which she had exacted as her reward. Her merchants and bankers were in every sizable port in the Mediterranean and the Middle East, from her own great city and the ancient port of Alexandria to the glittering city of Constantinople. Genoa had battled her only to be defeated at Chiogga in 1380 and to lose what she had attained as a maritime power. Venice was predominant, absolute controller of the Mediterranean trade and she was detested by the powers of western Europe".

The predominance of Venice in this very lucrative trade was destined, however, to be broken by various influences of the Renaissance, particularly by the voyage of the Portuguese, Bartholomew Diaz, in discovering the Cape of Good Hope. That same year Pedro de Covilham left Lisbon "and went east by way of Barcelona, Naples, Cairo, and Aden. At Aden, he embarked on a Moslem ship and crossed the Arabian sea to Cannanore, from where he went to Calicut. In Calicut, he saw large quantities of pepper and ginger and heard that other spices were brought there from more distant places. From Calicut he went to Goa and then to the island of Hormuz in the Persian Gulf, where he saw a great trade in spices. Having noted carefully all he had seen and heard in

India and at Hormuz, he returned to Cairo and sent a full report to Lisbon ".

From 1497 to 1499 Vasco da Gama and his valiant men became the first Europeans to reach India by an all-water route. They, too, " found Calicut the centre of a region producing cinnamon, ginger and pepper and, like Covilham before them, learned that many other aromatic and pungent spices came to this port from more distant spice lands ".

" When the news reached Venice, that city was shocked. Following on the discovery of Diaz, this voyage of da Gama was a serious matter. The merchants and bankers of Venice knew only too well what this news meant. Following the conquest of Constantinople by the Turks, the Venetians had brought their spices from the east by way of Egypt. Thus the news of the Portuguese success was equally shocking to the Egyptians. For the Sultan of Egypt, it meant the loss of the large revenue which he obtained from the movement of spices through his kingdom. Altogether, it was a bad day for the merchants and princes of Venice and the Middle East: Spices were making history "!

Christopher Columbus Sails West to Find the Spice Islands

Columbus did not have any botanically trained person with him on his visits to the New World in search of the spice islands of the East, and in his notes he much regretted his own inability to pass judgment on the profusion of new plants which he found. The only plants that suggested the spices of the Orient were the native capsicum peppers and a kind of bark, known today as " white cinnamon " (*Canella winterana*), which has a slight aromatic odor resembling that of true cinnamon. In some manner, however, he succeeded in persuading the King and Queen on the basis of this very meagre evidence that a second voyage in further search of the elusive spices would be worth the investment.

On his second expedition, on the island of Marie-Galante in the Leewards, " he found a tree whose leaves gave off the fragrant aroma of cloves. . . . There can be little doubt that the tree they found was a species of the genus *Pimenta*, native to the West Indies and adjoining mainland of Central America and belonging to the same family as the clove. It was, most likely, *Pimenta racemosa*, common to the Leeward and Virgin Islands, but it may have been *Pimenta officinalis* or allspice, which is much more abundant in the island of Jamaica. Being November, the tree would not be in fruit, and this is probably the reason why a conclusion was reached so quickly and the tree so promptly forgotten ".

" If the tree they found was an allspice tree, this would be the first European contact with a tree whose fruit has been one of the most desirable of all aromatic and pungent spices for over 300 years. Columbus was so eager to find spices that it is difficult to believe that the abundant allspice of Jamaica should have escaped his notice when he reached that island later in his explorations, yet this seems to be the case. It is understood that this spice was unknown to Europeans in Columbus's day and that Columbus could not inquire about a spice which to him did not exist, but had he found the natives using this spice or had he gathered it from the allspice trees of Jamaica, he would most certainly have carried it back to Europe as a new spice or, because he had ' no knowledge of these products ', as a species of clove since its aroma is similar to that of the clove. In the face of his repeated references to his lack of knowledge of plants, and spice plants in particular, it would not have been an unreasonable mistake for him to have

made. Later Spanish explorers were perhaps not better informed and they found the spice, but apparently thought it was a species of pepper and called it Pimienta, which accounts for its botanical name, *Pimenta officinalis*, and its other common names, pimento, Jamaica pepper, and clove pepper".

When Columbus died in 1506 "he had not reached the glittering courts of Eastern empires, nor smelled the fragrance of the spices which grew on the tropical isles of the Eastern Sea. For him, there had been no aromatic and pungent cloves, ginger, nutmegs, or mace; no fragrant cinnamon or cassia, not even a decent pepper! But the spices of the East Indies had led him to the West Indies, and to the land of America where his name is honored".

"The discoveries of Christopher Columbus opened the West Indies to the trade and commerce of the world and it was not long before the spices of the East were introduced into the West. Today, the world's finest ginger comes from Jamaica and the nutmegs and mace of Grenada are exported to all parts of America and Europe. The capsicum spices of the New World were introduced into the Old World, and today these useful peppers are cultivated in many parts of Europe, in Africa, India, East Indies, Japan, and other distant lands".

The Portuguese Master the Spice Trade

After John Cabot, born in Genoa and later a citizen of Venice, made his vain attempts under English auspices to reach the land of spices by following a northern route to the New World, the Portuguese began to consolidate their gains acquired through da Gama. First, under the command of Pedro Alvares Cabral and confronted by some fighting and other difficulties, they established spice-trading factories at Calicut, Cannamore and Cochin on the Malabar Coast of India. "The new spice trade was definitely under the control of King Emmanuel, and the factories were royal factories manned by royal officers who dispatched the spices of India to Portugal in royal ships. The kings of Portugal were not different from the ancient kings of Egypt in keeping control of the all-important and highly profitable spice trade".

In the succeeding years of the early sixteenth century the Portuguese continued to strengthen their gains toward controlling the spice trade. They gradually superseded the Moslems, who had so long monopolized the traffic, and they finally brought complete ruin to Venice, first by discovering the prime source of her trade in spices—the famed Spice Islands of the East Indies—and then by controlling them. "The Portuguese lost no time in consolidating their position in the East Indies. They were securely entrenched at Malacca and effectively commanded the strait, and they built forts at Amboyna, Halmahera, Celebes, Ternate and Tidore, where they had spice-trading factories. They were not very successful in protecting their interests in the Banda Islands, and because of the persistent, and at times violent, opposition of the natives, they were not able to fortify adequately the large islands of Sumatra and Java. On the island of Sumatra, the Moslem natives doggedly fought the Portuguese for the control of the pepper trade of the island, particularly in the north. On the island of Java, similar conditions obtained. The hatred which existed between the Christian invaders and the Moslem defenders cannot be overemphasized, and almost everywhere they went, the Portuguese met with cunning, subterfuge and frustration, if not violence. But the Portuguese were not deterred and went steadily ahead with their program of exploitation of the East Indies. Native junks were

found in the south China Sea, along the coast of Borneo and the Banda sea and, in the interest of monopoly, the Portuguese resorted to all sorts of methods to curtail these island traders. They did not intend that any spices should leave the East Indies except in Portuguese ships ".

" From Malacca, the Portuguese reached out to Burma, Siam, China and Japan. Long pepper grew in the forests of Burmese Tanasserim, black pepper in Siam, but these countries did not export their meagre spices at that time, and the Portuguese saw them more as potential markets ".

" The Moslems and Venetians throttled, the Portuguese now held a strangle-hold on the spice trade in Europe. The price of pepper and other spices began to soar in all parts of Europe and resentment grew as strong against the Portuguese as it had grown against the Middle East monopolists before them. Other European powers sought a means of breaking the grip of Portugal on the spice trade of the Orient, and intrepid mariners presented themselves at the courts of Europe with plans which would carry them to the Spice Islands and open a way for these powers to share in the great spice wealth of the East. Magellan sailed for Spain; Drake, Fenton, Cavendish, and Lancaster, for England; and before the 16th century slipped into the past, Van Houtman for Holland ".

Magellan's Quest and Further Attempts by the British

In September, 1519, Ferdinand Magellan, spurned by his own Portuguese king, sailed under the Spanish flag to seek a westward route to the Indies. Two years and nearly two months later, after enduring untold hardships and discovering the Straits that were ever after to commemorate his name, two of his ships entered the port of an island called Tidore. By that event the famed Spice Islands were finally reached by a westward journey around the earth. Magellan did not live to see the acomplishment of his mission, for he had been killed in combat in the Philippines six months earlier.

This fateful event deprived Magellan of personally enjoying the glory that would have been his upon later returning to Spain, but it was fortunate for later generations that one Antonio Pigafetta, a member of his staff, survived the journey. Pigafetta was an Italian gentleman and scholar who kept a faithful account of all that he saw and heard, and it is to him that we today are indebted, not only for information regarding the terrific hardships of the expedition as a whole but more particularly for his description of the cloves, nutmegs, ginger and cinnamon which the survivors found in the islands that they visited. The crew bargained for these commodities and gave in exchange agreed upon quantities of cloth, scissors, knives, looking-glasses and articles of brass and copper.

Under the command of Sebastian del Cano, Magellan's ship Victoria returned to Spain with a load of spices three years after having departed on the journey that was to accomplish the first circumnavigation of the earth, to observe for the first time the gain or loss in time by such a voyage, and to reach the great spice emporium by following the setting sun. " The cloves were sold at a most handsome profit, and Charles V of Spain was well pleased. He honored Sebastian del Cano with a coat of arms which included in its arrangement two cinnamon sticks, three nutmegs, and twelve cloves. He also gave him a very good pension. The golden trail of the spices was more brilliant than ever "!

Next the British, spurred by Magellan's conquest, endeavored to reach the Spice Islands by the Northeast Passage, around the North Cape of Europe, and

by the Northwest Passage which, it still was hoped, lay some where in North America. While all this was going on, "the Portuguese were waxing fat from their prosperous spice trade in the East Indies. They had obtained a share in the trade of the Javanese city of Bantam, from where three and a half million pounds of pepper were shipped yearly to China and India, and they had successfully concluded treaties with the Sultan of Brunei which not only opened up the pepper trade of Borneo, but enabled them to follow a better route from Malacca to the Moluccas and trade with the island of Celebes. Malacca had become a great spice-trading centre, to where all ships, large and small, that sailed the East Indian waters were bound to go and pay customs to the Portuguese. From this port, the Portuguese monopolized the clove trade of the Moluccas and the nutmeg and mace trade of the Banda Islands. But they had never known real peace with the natives. In the great pepper land of Northern Sumatra, the Achinese king stoutly opposed them and successfully carried on trade in pepper and other spices with Moslem merchants from Mecca. Moslem traders in Java steadily sniped at their trade with the Spice Islands, and shipped cloves, nutmegs, and mace to the Red Sea. Portuguese rapacity brought about an uprising in the Moluccas and in 1574, their fortress at Ternate fell to the Moslems. Then, in 1579, Francis Drake came, not by a northeast or northwest passage, but in the track of Magellan. It was the beginning of the end of the Portuguese monopoly of the spice trade of the East".

In September, 1580, Drake returned to Plymouth, England, in his famous ship, the Golden Hind, and brought with him a load of spices. Other Englishmen followed Drake in Britain's effort to reap profits from the lucrative spice trade of the Indies. "But it was not the English who broke the power of the Portuguese in the East Indies; they concentrated more on India. It was the Dutch. The merchants of Holland were an enterprising lot and they were every bit as keen as the London merchants to reach the Spice Islands. In fact, they were determined to get their share of the highly profitable spice trade; they were already at war with Spain and they were prepared to fight the Portuguese in the East Indies if necessary. In 1595, they supplied the ships and money to send an expedition to the East Indies under Cornelius Van Houtman, and in 1596, the shadow of the Dutch fell across the Portuguese in Bantam".

The Dutch and the English

In 1597 Van Houtman brought home three shiploads of pepper and nutmegs. Only 89 of the 284 men who had sailed from Holland returned, so costly in lives had the expedition been as the result of scurvy and other hardships. "The success of Van Houtman fired the imagination of the people at home and stimulated the merchants of Amsterdam into immediate action. The pepper and cinnamon of Sumatra, Java, and Borneo; the cloves of Ternate, Tidore, Amboyna, and other islands of the Moluccas; the nutmegs and mace of the Banda Islands—all were now within reach. Ships were speedily made ready for the long voyage, manned with sturdy sailors, officered with competent, daring navigators, and staffed with discerning officials. In the year 1598, no less than five expeditions left Holland for the East Indies; all told, there were twenty-two ships, thirteen of which followed the Cape route, and nine attempted the passage through the Straits of Magellan".

These expeditions "made a good impression on the native sultans, opened trading stations, and generally laid the foundation for the future domination of the East Indies by the Dutch. The spices were making history and it was a bad day for the Portuguese".

"The story of the spices in the 17th

century is the story of the decline and fall of Portuguese power in the East and of the conflict between the Dutch and English for the mastery of the spice trade ".

As part of this struggle, and angered by the high prices demanded by the Dutch, the English established the famous East India Company for developing their part in the spice trade. In September, 1603, one expedition dispatched by this company " brought to England enough pepper to break the Dutch hold on the market .... We do not know what the market for cloves was at that time, but history records that a shipload of cloves purchased in the Spice Islands for £2,948 in 1606, brought the sum of £36,287 when sold in England two years later ".

In order to meet this threatening competition, the Dutch merchants of Amsterdam, who had been fighting among themselves as well as against the English and Portuguese for control of the trade, banded together and formed the equally famous Dutch East India Company. After battles with the Portuguese, the English and the natives, the Dutch merchants eventually gained control of the producing regions whence came the pepper, cinnamon, cloves, ginger, mace and nutmeg which they all were striving to monopolize. In 1621 they were in a position to change the name of Jacatra, on Java, to Batavia. Some time thereafter, " from the Dutch headquarters in Batavia, a directive was issued affecting the cultivation of clove and nutmeg trees in the East Indies. On all islands, except those of Amboyna and Ternate in the Moluccas and the Banda group, clove and nutmeg trees were ordered extirpated. This wilful destruction of trees, which require years to bring their spices to fruition, reduced the production of cloves, nutmegs, and mace to one-fourth of that before the coming of the Dutch to the Indies. This was the Dutch method of creating a scarcity of these fragrant and highly desirable spices to force their prices up in the European markets for the benefit of the directors and shareholders of the Dutch East India Company ".

At the close of the 17th century the Portuguese spice trade in the East Indies was crushed, the English were left with but a remnant of their former trade, and the Dutch were " the undisputed masters of the East Indies, reaping the wealth of a great spice monopoly. The demand for Eastern spices had steadily increased in Europe and the trade was perhaps the most profitable in existence at that time. The number of uses for the spices in flavoring food and beverages, in medicine, cosmetics and perfumery had multiplied. Spices were sought after by all who could afford them. As in ancient times, the spices made treasured gifts between people. They were also sometimes presented to state dignitaries on special occasions and in festive seasons; offered as political bribes; given as bonuses to the dockworkers who unloaded the spice ships; bequeathed in wills; and used as rent. The term 'peppercorn rent' means today a nominal rent, but in those days it represented real value. Cinnamon was perhaps the most desired of all the fragrant spices, particularly the bark grown in Ceylon which had a value on the European market many times that of the Malabar product, or the cassia of the Far East. The trade in this spice was one of the most profitable of all to the Dutch East India Company, which did not hesitate to burn large quantities of the bark to keep its price high. Not only had the trading companies profited handsomely from their ventures into the East Indies, but the revenues of their respective countries had been materially increased by the import and export of pepper, cassia, cinnamon, cloves, ginger, turmeric, mace and nutmegs ".

" Halfway through the 18th century, the tide of fortune began to change for

the Dutch East India Company. There were many reasons for this, but the principal were the steps taken by the French and British to break the Dutch monopoly by introducing spice plants into their own overseas colonies, the loss of Dutch possessions in India, the export of spices from India by the English East India Company, the British blockading of Dutch East Indian ports, and piracy and smuggling in the waters of the Indies ".

" The Dutch had angered Europe by making her pay dearly for cloves, nutmeg, mace, and cinnamon through their rapacious policy of curtailing production and creating artificial scarcities of these commodities. For a hundred years they had enjoyed naval supremacy in the Indies, and kept the foreigners from their spice-trading ports. But monopolies of this kind can be very harmful to the monopolists ".

In the latter half of the 18th century, despite Dutch vigilance, the French succeeded in introducing cloves, nutmeg and cinnamon plants from the East Indies into the islands of Reunion, Mauritius and Seychelles in the Indian Ocean, and into French Guiana in South America. In Amboyna, however, according to one navigator, " cloves were in such abundance that the Dutch authorities at Batavia sometimes ordered a large number of clove trees to be extirpated and fixed the number of trees that should be in production. Thus, by a resolution of the year 1768, they ordered that the propagation of the clove trees should cease till their number was reduced to 550,000; the number of trees both young and fruit bearing was then 759,040 ".

" According to this navigator, at the time of his voyage to the East Indies there were 3,000,000 pounds of cloves in the Dutch warehouses at Batavia, of which not more than 200,000 could be disposed of annually in the Indies. In addition to the cloves stored in Batavia, there was enough stock of the spice in Holland to meet the needs of Europe for ten years. Such an abundance of cloves was a threat to the handsome market the Dutch strived to maintain and, consequently, large quantities of cloves were ' committed to the flames ' from time to time by the Dutch East India Company ".

" Similar conditions existed in nutmeg production and quantities of this spice were also periodically destroyed by fire to maintain the Dutch monopoly ".

In 1788 the British occupied the Malayan island of Penang, and about eight years later they successfully transplanted clove trees from the Moluccas into that island. By 1799 the ascendency of the British had progressed to such a degree that the Dutch East India Company was dissolved, and " the affairs of the Company were taken over by the Dutch government. The Dutch East India Company had been a progressive and powerful factor in the colonizing and trading affairs of the Netherlands for almost two hundred years; at the height of its prosperity, in 1669, the Company had one hundred and fifty trading ships, forty ships of war, one thousand sailors, and paid a dividend of forty per cent ".

In 1818 the clove tree was introduced from Mauritius into Zanzibar, and today Zanzibar, with the adjoining island of Pemba, produce by far the greater part of the world's supply of cloves. Later the nutmeg tree was successfully introduced into the West Indies. All these efforts over many years, together with territorial conquests by the British against the Dutch, completely destroyed the Dutch monopoly on spices in the East Indies.

" It is now four hundred and sixty years since Bartholomew Diaz doubled the Cape of Good Hope in the search for an all-water route to India, so that Portugal might wrest from the Moslem traders, the Sultan of Egypt, and the merchants of Venice the profitable spice

trade of the Orient. And we have seen how greatly this spice trade has shaped the course of history since that time. It is difficult for us, who buy our supplies of pepper, cassia, cinnamon, cloves, ginger, mace, and nutmeg so casually and so cheaply, to believe that there was ever a time when these spices were so eagerly sought after and represented so much wealth and power that destiny itself was indivisible from them ".

" The introduction of the highly valued spice plants of the East Indies into other countries and the maritime intercourse between east and west gradually changed the spice-production situation. Today, the East Indies, while still the largest pepper-producing center of the world, is no longer the great emporium for the fragrant spices it was in the days of the Dutch ascendency. Nutmegs and cloves are still exported from the Spice Islands, but a far larger export of nutmegs is carried on from the island of Grenada in the West Indies and Zanzibar is the leading source of supply for cloves. The export of cassia from Batavia is not nearly as great as the export of the highly esteemed Saigon cassia from Indo China ".

" Ginger was introduced into the West Indies by the Spaniards in the 16th century and today, Jamaica exports the finest ginger of all and by far the greater part of the world's requirements; other ginger is exported in small quantities from Africa and Japan. China exports cassia and preserved ginger. Ceylon is still the only important exporter of the delightfully fragrant *Cinnamomum zeylanicum;* that produced in the Seychelles and some other places is not a factor in world trade ".

" The Malabar coast ports export some of the world's best pepper and also a pungent ginger. Burma is not a spice exporting country; the long pepper originally found in the woods of Tenasserim is now cultivated in Bengal, India and also in Java. Siam is today at her lowest point as a producer and exporter of pepper; in the 17th century, her pepper was the cause of contention and conflict among foreign merchants, but today nobody fights about it. The different varieties of capsicum peppers native to Central America were early introduced into Africa, India, East Indies, Japan, and other countries. Today, these peppers are exported in all sizes and varieties from many parts of the world."

Utilization Abstracts

Peanuts. Considerable study has been devoted in recent years, particularly at the Southern Utilization Research Branch of the U. S. Department of Agriculture, to promoting greater utilization of peanuts. In a manner which defies abstracting here because of its very succinct though brief resume of this study, The Garden Journal of The New York Botanical Garden (Jan.–Feb., 1955) contains an excellent summary of this work.

Algae as Food. Perhaps no other potential aspect of plant utilization appeals so much to the imagination as does the possible supplementing of agricultural practice by large-scale cultivation of unicellular algae as a source of human food. Attention has been drawn to this in several past issues of Economic Botany. Two more contributions on the subject are contained in *The Scientific Monthly* (Jan., 1955).

BOOK REVIEWS

Materia Medica Vegetabilis. E. F. Steinmetz. Two volumes, 479 pages, continuously numbered. Published by the author, Keizergracht 714, Amsterdam, Netherlands. 1954. $15.75.

These two volumes contain brief accounts, in four languages (English, Dutch, German, French) and ranging in length from a single short sentence to an extended paragraph, on 1473 numbered plant products of pharmaceutical value. The author refers to himself as an "herbalist", largely influenced in compiling the two volumes "by the increasing interest which the medical profession is again taking in drugs obtained from the vegetable kingdom".

The nearly 1500 items are alphabetically arranged according to the principal word in the Latin pharmacological names of the products, and each is followed by the scientific name of the plant yielding the product. In the great majority of cases, the principal word in the name of a product is a form of the related generic name, and in such cases, a reader, consulting the volumes to determine the products obtained from a particular genus or species, will readily find the information. For instance, the pharmaceutical product of *Cypripedium pubescens* is listed as Radix Cypripedii in the alphabetical sequence of the "C's", and that of *Potentilla reptans* is listed as Herba Potentillae Reptantae in the alphabetical sequence of the "P's". In some cases, however, the principal word in the name of a product is derived from a species name; the product of *Prunus spinosa*, as a result, is found as Fructus Pruni Spinosae under the "S's". In other cases there is no similarity between a plant name and that of its product—*Urginea maritima* is the source of Bulbus Scillae Albi, also listed under the "S's". Since there is not any separate index of botanical names, any one seeking information that happens to fall in either of the last two categories, will be disappointed in these volumes as a reference work. The last item in the two volumes, under "Z", is "Herba Ziziae", obtained from *Thaspium aureum*, but anyone wanting to know whether *Thaspium* is the source of any pharmaceutical product is deprived of the information, although it is contained in this study.

To one interested in plants as such as well as their products, this omission of a plant-name index is very disconcerting. But to those whose primary concern is with phytotherapy from a medicinal angle exclusively, the omission, very likely, is unimportant. Neither will they be disturbed by the utter lack of the slightest note regarding where the hundreds of plants named, grow. The real value of the study lies in its making available in four languages, brief information of the medical uses to which pharmaceutically-named products have been put, without, however, appraising those uses in the light of critical research.

The Botanical Lore of the California Indians. John Bruno Romero. viii + 82 pages. Vantage Press. 1954. $2.50.

Years ago, after the Indians of the American Pacific Southwest had been severely decimated several times by epidemics, their medicine men allegedly reduced the fatalities in the next scourge of black measles and smallpox by means of compounded-herb steam baths which contained the extracts of sage, creosote bush, pepper plant, yerba santa and maidenhair fern. Many other plants also were of use in their plant lore, and about 150 of them are botanically identified in this book by the nephew of a Chief and Medicine Man of the White Water and Palm Springs area in California.